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AUTHOR	Smith, Ernest K.; And Others
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ABSTRACT

The system control facilities in broadband communication systems are discussed in this report. These facilities consist of head-ends and central processors. The first section summarizes technical problems and needs, and the second offers a cursory overview of systems, along with an incidental mention of processors. Section 3 looks at the question of the computer needs laid upon the central processor at head-ends or subhead-ends by particular service requirements; the following section considers the problems of coupling the computer into a communications system. Privacy and security, worrisome areas in time-shared computers to say nothing of cable television systems, are considered in section 5, while performance standards, both present and future, are treated in section 6. Section 7 deals with the measurements required by Federal Communications Commission regulations. A set of appendixes covers such areas as the characteristics of television signals and existing standards. (Author)

OT REPORT 73-13

A SURVEY OF TECHNICAL REQUIREMENTS FOR BROADBAND CABLE TELESERVICES VOLUME 4

OT

U.S. DEPARTMENT OF COMMERCE/Office of Telecommunications

SYSTEM CONTROL FACILITIES: HEAD-ENDS AND CENTRAL PROCESSORS

ERNEST K. SMITH
RAYNER K. ROSICH
EDGAR C. HAYDEN
LAURENCE L. MELANSON

U.S. DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary

OFFICE OF TELECOMMUNICATIONS
John M. Richardson, Acting Director

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OFFICE OF TELECOMMUNICATIONS

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FOREWORD

As information transfer becomes more important to all levels of society, a number of new telecommunication services to homes and between institutions will be required. Many of these services may require broadband transmission. The new services may, in part, evolve from those provided by cable television.

This is one of a series of reports resulting from a survey of the CATV industry and related technological industries. The survey identifies some of the important technical factors which need to be considered in order to successfully bring about the transition from the technical state of today's cable television and services to those new teleservices which seem to be possible in the future.

The current and future broadband capabilities of telephone networks are not discussed since they are described in many Bell Laboratory and other telephone company publications. Also, the tremendous load projected for common carrier telephone and data systems in voice and data communication suggests that two-way, interactive, broadband networks, not now in existence, may be required in addition to an expanded telephone network. The many aspects of economic viability, regulation, social demand, and other factors that must be considered before the expectation of the new teleservices can be fulfilled are not within the scope of these reports. These reports concentrate on technical factors, not because they are most important, but because they have been less considered.

A report about the state-of-the-art and projections of future requirements in a complete technology draws material from a vast number of sources. While many of these are referenced in the text, much information has been obtained in discussions with operators, manufacturers, and consulting engineers in the CATV industry. Members of the

National Cable Television Association, particularly, have been most helpful in providing information, discussing various technical problems, and in reviewing these reports.

Because of the substantial amount of material to be discussed it was believed most desirable to present a series of reports. Each individual report pertains to a sub-element of the total system. However, since some technical factors are common to more than one sub-component of the system, a reader of all the reports will recognize a degree of redundancy in the material presented. This is necessary to make each report complete for its own purpose.

The title of the report series is: A Survey of Technical Requirements for Broadband Cable Teleservices. The seven volumes in the series will carry a common report number: OTR 73-13. The individual reports in the series are sub-titled as:

A Summary of Technical Problems Associated with Broadband Cable Teleservices Development, OT Report No. 73-13, Volume 1.

Subscriber Terminals and Network Interface, OT Report No. 73-13, Volume 2.

Signal Transmission and Delivery Between Head-End and Subscriber Terminals, OT Report No. 73-13, Volume 3.

System Control Facilities: Head-Ends and Central Processors, OT Report No. 73-13, Volume 4.

System Interconnections, OT Report No. 73-13, Volume 5.

The Use of Computers in CATV Two-Way Communication Systems, OT Report No. 73-13, Volume 6.

A Selected Bibliography, OT Report No. 73-13, Volume 7.

W. F. Utlaut
Project Coordinator and Deputy Director
Institute for Telecommunication Sciences

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A SURVEY OF TECHNICAL REQUIREMENTS FOR BROADBAND CABLE TELESERVICES

SYSTEM CONTROL FACILITIES: HEAD-ENDS AND CENTRAL PROCESSORS

Ernest K. Smith, Rayner K. Rosich, Edgar C. Hayden, and Laurence L. Melanson*

ABSTRACT

This report is concerned with the system control facilities in broadband communication systems. In CATV systems these are the head-ends and central processors. Technical problems and needs are summarized in Section 1 immediately following. Section 2 offers a cursory overview of systems and mention of processors is made only incidentally. In Section 3 the question of the computer needs laid upon the central processor at head-ends or subhead-ends by particular service requirements is looked at, and in Section 4 the problems of coupling the computer into a communications system are considered. Privacy and security, a worrisome area in time-shared computers to say nothing of CATV systems, is considered in Section 5 while performance standards, present and future, are treated in Section 6. In Section 7 we look at measurements required by current FCC regulations, those which the cable operator will want to make anyway, and those which future needs would appear to require. Finally a set of appendices treat such areas as the characteristics of television signals and existing standards.

*The authors are affiliated with the Institute for Telecommunication Sciences, Office of Telecommunications, Department of Commerce, Boulder, Colorado, 80302

1. INTRODUCTION

1. Computers are being used in relatively modest ways in current demonstration systems, but the computer field is a highly developed area in its own right. Of the various directions in which the development of broadband cable teleservices can be usefully advanced, it would appear that one of the most fruitful would be to bring to bear the potential of computers on cable systems.

2. Joint planning at the national level for computer communications and CATV, two fields now being treated separately (IEEE, 1972), appears not only logical but urgent.

3. With the certain increase in the use of computers in mass-subscriber cable systems, the problems of privacy and security will become rapidly critical. The issue of individual privacy in a computer age has been a matter of concern at the highest governmental levels and broadband cable systems will be a good case in point. Security of computer-stored files has been a subject of extensive discussion within the computer fraternity and is technically a very difficult problem.

4. The availability of computer software of different levels (monitor, executive, problem-oriented languages, and applications) is very different. Monitor (device driver) software largely exists, executive (user communication) software is insufficient. Problem-oriented language software for constructing service programs is largely non-existent, while applications (service providing) software may be considered to exist to a limited extent, though perhaps not in the right form. The prediction is that the software problem will be both expensive and critical.

5. There are probably ways in which clever usage of computers in the head-end can materially increase the number of subscribers served by a given system.

6. The normal operation of broadcast television assumes that a maximum of 7 VHF television channels will be received at any locality. CATV systems assume that 12 VHF channels can be received. This filling of channels produces problems in head-end equipment in keeping down the level of the various undesired signals which crop up in each of the non-linear operations carried out in the head-end. This problem becomes greater as these 12 channels fill up and becomes intense when sub-band, mid-band and super-band channels are used.

7. In considering the signal degradations which occur in broad-band cable operations, it is clear that a systems approach to the problem is important. A difficulty, however, is that the meaning of terms used to characterize these degradations does not adhere to a universal standard. Signal-to-noise ratio is a case in point. It is necessary to ascertain just how signal-to-noise radio is defined, e.g. for what bandwidth, is it cumulative, is it changed with the insertion of synchronization pulses, etc.

8. The need for careful thought as to just what measurements are really needed and how they can be more economically carried out is an area of immediate concern (see Section 7).

9. A need exists for a program of standards development for CATV as the industry evolves, particularly in signal processing and distribution (see Section 6). New areas can be expected to open up as the cable systems evolve.

2. HEAD-END SYSTEM CONFIGURATION

The head-end generally contains equipments to control, to change frequencies of off-the-air signals where necessary, to process off-the-air signals and studio signals in order to prepare them for transmission down the cable, to route upstream and downstream transmissions, to insert pilot tones, etc.

The equipment at a head-end includes computers, automatic origination equipment, VHF/UHF and microwave antennas and amplifiers, video and FM channel processors, modulators, filters, AGC, and test components.

For downstream transmission of off-the-air signals the input terminals are those of the antenna pre-amplifiers while the output terminals are the points at which signals from all channels are combined, following AGC control, carrier insertion devices, and test points in a common cable or other transmission media. The output terminals connect to the input terminals of the trunk system or network. The output terminal from a head-end may be an interconnection circuit tying to head-ends from different systems or it may be to subhead-ends of the same system. The signal processing options conventionally utilized in the head-end of a one-way CATV system are illustrated in Figure 1.

In the upstream direction the input terminal would receive signals from the trunk system and either process them at the head-end or relay them to another head-end if remote processing is required. The location and configuration of head-ends will depend upon the circumstances. In rural situations one is apt to find the head-end located in the headquarters of the CATV system, with studios in the same building and the master antenna mounted on the roof or in a nearby location. In the urban situation the master antenna may be located at some distance from the head-end equipment, which again may be separated from the head office and

studio facilities. In addition, microwave service may be brought in through a different transportation trunk. Figure 2 illustrates a typical system for a large town (or city) where the antenna field and downtown hub are separated so that the functions we are concerned with are actually carried out in two places. At the antenna site, TV channels 3, 4, 8, 13, and 33 and the FM band are picked up off the air. In order that the transportation trunk need only carry signals at frequencies below 108 MHz, TV channels 8, 13, and 33 are converted down to vacant low VHF channels prior to being sent to the downtown hub equipment. If more channels were to be received at the antenna site they could be:

1. converted to sub-band (6-30 MHz) and/or mid-band (120-174 MHz) and sent over the same cable,
2. a second cable could be employed and the same frequencies reused, or
3. the signals could be up-converted and a microwave relay could be used.

Notice that in the configuration of Figure 2 the signals never go down to baseband (0-6 MHz). Also notice in the case of TV channels 3 and 4 and the FM band, no change in frequency is necessarily involved in the head-end complex at all. (In the example shown intermediate frequency processing in the vicinity of 45 MHz is employed.)

A different approach is illustrated in Figure 3 where all signals are demodulated to baseband at the head-end. This results in greater flexibility as any outgoing channel can be fed by any of the available signals through the switching matrix.

Figure 4 illustrates a single-cable, two-way system. Here a computer--peripheral--interface equipment has been added to the head-end. In this instance signals go from the head-end to the subscriber (downstream) at frequencies above 54 MHz. Signals from the

subscriber to the head-end (upstream) typically use the 6 to 30 MHz sub-band. Frequency designations in common CATV usage are:

6-30 MHz . . . Sub-band channels a, b, c, and d
54-88 MHz . . . Low VHF* channels 2, 3, 4, 5, and 6
88-108 MHz . . . FM broadcast
120-174 MHz . . . Mid-band channels A, B, C, D, E, F, G, H, and I
174-216 MHz . . . High VHF channels 7 - 13
216-300 MHz . . . Super-band channels J, K, L, and M
470-900 MHz . . . UHF band channels 14-83
10700-10950 MHz. . . Community antenna relay service (CARS band).

In the case of two-way transmission the head-end will look something like Figure 4. However, it must be understood that in most future systems what will actually exist is a combination of Figures 2, 3, and 4. Descriptions of head-ends may be found in Reinfelder (1970), in Mason, et al. (1972), in Taylor and Janes (1970) and in booklets of the various manufacturers of head-end equipment.

2.1 One-way Systems

2.1.1 Present Problems and Limitations

The conventional function of the head-end is to collect TV signals from a variety of sources, process these signals (if necessary) into the standard vestigial sideband signal (in North America), adjust the level of these signals, and combine them. Perhaps some FM signals would be added in the 88-108 MHz band, and usually pilot carriers are inserted for AGC and slope control in the trunkline amplifiers. This combined signal is fed to the trunk lines at a level as high as that out of the trunk-line amplifiers which follow. Ten miles appears to be a practical limit

*72-76 MHz is allocated to Operational Fixed, Radio Astronomy, and Aeronautical Radionavigation.

for a single-cable trunk with present amplifiers, (but see the companion report on signal transmission and delivery). Alternatively, the signal may be up-converted and transmitted to a subhead-end as a block of channels on a CARS-band microwave system.

Locally generated video signals (live cameras, film, tape, or character generators) require a modulator, a carrier generator, a side-band filter, and a sound carrier generator and modulator to prepare a signal for the cable. Signals which arrive by way of FM microwave terrestrial or satellite link) require demodulation to baseband, then remodulation as for local video. Signals which are taken off-the-air from VHF TV stations may be:

1. simply amplified, and leveled and supplied on the same channel to the cable,
2. translated with a local oscillator and mixer to a different channel, or
3. may be demodulated to baseband and then remodulated as a local signal.

UHF-off-the-air television signals (470-806 MHz) are above the frequency limits of cable systems; they must be translated to a VHF channel or demodulated and remodulated on a VHF channel. Signals received at the head-end over a CARS-band single sideband AM system can be handled in the same manner as a UHF signal, an exception being that a whole block of TV signals would be frequency translated into the VHF band. For an FM CARS-band system the signal must be reduced to baseband and demodulated.

A certain amount of distortion is generated whenever an AM-TV signal is demodulated. This is an argument in favor of frequency translation rather than demodulation-modulation. It is also an argument in

favor of AM-SSB CARS band usage instead of FM in that the former may be frequency translated while the latter must be demodulated.

Designing a head-end involves more than simply deciding what to do with each channel and then buying boxes to do it. A number of local oscillators will be required; these must be shielded. After each signal is fed to a mixer, modulator, or demodulator the resultant output must then be filtered to remove any appreciable undesired signal. Spurious signals at the head-end which fall in used TV channels must be at least 60 dB below the desired signal. The same applies to the spurious signals created in any manner in the head-end. For example, overloaded single-channel amplifiers will mix carrier with sound and color sub-carriers, producing spurious signals in adjacent channels which may be troublesome before the overloading is noticeable in the channel in question.

Filters used to remove spurious signals, to separate channels for leveling (AGC) purposes, or to remove undesired off-the-air signals, must not only be ripple-free in the passband, but must also have very linear phase characteristics. Phase correlation may be necessary (Sleven, 1972; Everette, 1972). Differential phase distortion in a SSB TV signal results in drastic picture distortion, 180° phase shift changes white to black, (the color situation is even worse).

The audio channel may be demodulated and modulated (a relatively simple process) even when this is not done with the video channel, in order to meet the FCC requirements that the sound carrier to be 13 to 17 dB below the video carrier. Also, audio announcements could thus be patched into any or all channels.

Off-the-air receiving antennas must be located so as to receive the desired signal with as little multi-path component as possible and, if the received signal is weak, the receiving antenna should not be pointed

over sources of man-made interference. The receiving antenna should not be placed very near any output cable from the head-end where leakage could cause ghosts. Antenna pre-amplifiers are available with noise figures under 4 dB, for improving the quality of weaker signals. If the antenna site is located a great distance from the cable service area, microwave could be used to link the two areas.

2.1.2 Future Systems

Baer (1971) categorizes new communications services in terms of one-way broadcast services which involve, firstly, the addition of channels of the same type which are currently available, as well as, subscription channels and; secondly, one-way addressed services. The additional channels for the one-way broadcast services would be used for TV entertainment programs, instructional programs, local events coverage, local program origination, community bulletin board, municipal services information, local ombudsman, FM radio, foreign radio, and recorded music. The head-end requirements stemming from these additions would be simply more signal processing, multiplexing and origination equipment. The addition of subscription channels such as movies, entertainment programs, instructional programs, and sports and special events would require a signal scrambler or encoder in the head-end equipment, as well as, the items above. The second category--one-way addressed services--includes electronic mail delivery, newspaper and periodical delivery, and selective video. These would require the addition of head-end information storage facilities, a document scanner, an address generator, and a communications controller.

In general, it can be said that future one-way systems will require more capacity, better technical standards, and more reliable equipment. Further, as category two becomes needed, more information storage, processing and control equipment (e.g. a minicomputer) will be required.

2.2 Two-way Systems

A market for two-way broadband communications is yet to be demonstrated for the central-processing-center-to-home-subscriber-terminal configurations for any of the proposed uses with the exception of entertainment and, possibly, education. However, the promised potential is clear, and many enterprising manufacturers and/or operators have prototype systems. Jurgen (1971) describes seven of these systems. Inasmuch as the permutations of head-end configurations are limitless in theory, it is necessary to impose practical limits. The systems outlined by Jurgen are all aimed at the mass subscriber and do not include the intra- and inter-institution systems. Baer (1971) in his tabulation of equipment requirements for various categories of service suggests the following head-end requirements:

1. Narrow-band subscriber response services. Required head-end equipment includes central polling scanner, communications controller (mini-computer), files, displays and other peripherals.
2. Subscription television. Head-end equipment requirements are a signal encoder and a billing mechanism.
3. Shared two-way services. Head-end equipment requirements include the above, plus equipment to recognize and queue requests, enable and disable subscriber equipment.
4. Subscriber initiated services. Items 1, 2, and 3 above, plus source data bases (digital data, pictures, etc.) connected to a central controller; billing mechanism.

5. Point-to-point services. Head-end equipment required would be a store and forward processor; equipment to set up private or multiparty channels.

The Committee on Telecommunications of the National Academy of Engineering submitted a report in June of 1971 to the U.S. Department of Housing and Urban Development. The NAE report discusses four basic communication networks for the future;

1. The telephone network for transmitting pictures, voice, and written material between two points.
2. A network based on existing cable television systems, which can distribute information from central facilities to offices or homes, with a capacity of as many as 30 television channels and a limited call-back capacity for polling or making requests.
3. A broadband communications network carrying up to 30 equivalent television channels in both directions interconnecting major public institutions and large commercial enterprises.
4. A multipurpose city-sensing network to collect data on such items as weather, pollution, traffic, vehicle location, and power status.

The 7 systems described by Jurgen (1971) fall largely within category 2 of the NAE networks. However 3 have elements of the switched network of NAE #1. In addition a different 3 have the capability of carrying out many of the services of network #4 above.

Let us look then at the specific demands put on head-end equipment by these systems. Four of the 7 have computers as important adjuncts to the head-end equipment. These requirements are treated in Section 3.

Computers loom as such an important area in broadband cable distribution systems that they are considered separately in Sections 3 and 4. Switching is a complex and highly developed area in itself. There is a distinction between switching different programs onto the same channel and switching a subscriber between channels. On-channel switching is an area where a whole technology has been built up over the years in the television industry to accomplish, among other things, program switching without loss of synchronization (and hence tearing of the picture in the course of switching). The time synchronization problem in channel switching is both a time and space problem. For example, in a given TV station, despite the fact that all origination equipment may be driven from the same master oscillator, it is still necessary to introduce extra cable footage from one source relative to another in order to bring them into adequate synchronization to prevent tearing of pictures in switching.

3. HEAD-END COMPUTER PROCESSING REQUIREMENTS

3.1 One-way Systems

From the information obtained so far, there is little or no present use of processing functions requiring a digital computer.

One possible future use of digital computers that could be found deals with special displays (generating, storing, programming, and scheduling). Classified ads, updated weather information, program schedules, retail ads and swap shop listings as well as, newswire or weather information can all be automatically stored and scheduled for display. Also 35 mm color slides can be programmed as background to the textual information displayed on the TV screen (Sales Brochure, 1972a).

Another possibility that should be considered in one-way systems is the use of computers to maintain video quality. A continuous, real-time analysis of the condition of the line from the central office and the use of "auto line conditioning" via a downstream computer could permit modification of the video signals to remove noise, interference, and distortion. Also the possibility of using powerful error detection and correction techniques, along with the signal processing described above could permit more economical network design which would not require special cable and amplifiers. Additionally, the use of computers might make possible the utilization of several smaller bandwidth switched telephone circuits for the transmission of the network information. This could do away with the laying of private cable. The computer can then not only be used to control the multiplexing of information to several transmission lines, but can also be used to perform bandwidth compression by techniques, such as Fourier transforms or polynomial fitting (sending the coefficients of a polynomial which has been chosen to represent the signal).

3.2 Two-way Systems

All two-way cable systems necessarily include the delivery of video signals from the head-end to the subscriber (downstream), but the upstream signals (subscriber to head-end) can be pulse, audio or video. Interestingly enough, there are probably more cable systems using video/video in normal commercial operations than video/pulse or video/audio. This comes about because one feature of the operating cable system with the capability for two-way (extra cable or bi-directional amplifiers) makes it a simple matter to originate programs from several locations in the distribution system. These video signals are normally sent upstream from the origination points to the head-end from where they are distributed to the system. This constitutes two-way video operation over part of the system, but is not interactive video. Most two-way interactive CATV has been in demonstration systems as Baer (1971) notes. As mentioned earlier, Jurgen (1971) in his article describes seven experimental systems. Four of these systems involve the use of computers for communication control, special services, billing and so on. The three others involve remote-switched-line systems and at present do not involve the use of computers at all. However, the possibility of the incorporation of computers to perform the switching function, as well as billing, access control, and so on certainly exists. Two (MITRE, 1972; Volk, 1971; Setten, 1971a; Setten, 1971b; Callais and Durfee, 1972; Callais, 1972) of the four systems are well documented in the literature and basically involve the use of a standard, general purpose, mini-computer with roughly 24K - 32K (K = 1024) words (about 16 bits long) of core memory, 512K - 29000K characters of rapid access disc storage, and other standard peripherals such as magnetic tapes, card readers, graphic display terminals, line printers, and so on (see Fig. 5). In addition when interfaced to the cable, they

must also have the necessary hardware to control transmission and reception to and from the cable. The third (Vivian*, 1972) of these also involves the use of a general purpose mini-computer, but with an interesting twist. Instead of handling I/O (Input/Output) with the cable via standard I/O bus interrupt techniques, it issues a polling signal to all terminals on the network, sets up a direct memory access (DMA) arrangement for the return information, and then returns to other processing chores for a period of time sufficiently long enough to allow for the maximum delay on the CATV network. Although one would expect the response time to rise, in this fashion it is claimed that more terminals can be processed in less time. It has not been possible to obtain information on the fourth of these systems. Each of these systems has its advantages and disadvantages, but it is too early yet to judge the overall superiority of any of them. Providing that development funds are available equally to all (which unfortunately is not the case), time will allow clarification of their relative merits.

The question of future systems is a difficult one in that insufficient specifications are available with which to begin design. The question of the level of service desired is not yet answered and requires much more research in itself. Is the system to be only a very simple fixed-format, limited-choice, two-way system? Is it to be a general purpose information handling system? Should it allow for completely general message switching? Should it be extensible? How general can the system be made without running afoul of the postal service and the telephone company? These are policy questions which must be answered before design can begin. One must know "what is to be designed" before one can "begin to design."

*Private communication on interactive video (formerly VICOM).

After the design criteria are available, design and simulation need to proceed. The need for simulation may not seem obvious since the network configuration presently accepted is rarely, if ever, questioned. For one-way or very limited two-way service, the present combined "star-tree" configuration is probably the best choice. If a general purpose information handling capability is desired, however, other designs (Farber, 1972; Roberts and Wessler, 1970; Baran, 1964; Tymes, 1971) such as distributed networks (for example, the ARPA computer network, Heart, et al., 1970; Carr, et al., 1970; Ornstein, et al., 1972; Frank, et al., 1972; Crocker, et al., 1972) need to be considered (see Fig. 6). The various reasons and approaches can be found discussed in a report by Baran (1964) and in the various ARPA net documents (Roberts and Wessler, 1970; Roberts, 1972). The real question here, as always, is bandwidth versus response time. This topic is introduced here because of the effect that it has on the details of the design criteria of the processor involved (Heart, et al., 1970; Ornstein, et al., 1972).

Once the simulation is done and the design criteria exist, sufficient literature exists (Telecommunications, 1972; Pyes, 1972; Fife, 1968; Becker, 1972; Gourley, 1972) to help one choose the most desirable machine for the purpose. As Fife (1968) notes, such "evaluation should always produce evidence of sound technical consideration, which leads to the matter of collecting evaluation data... there are three sources:... experiments and usage experience; simulation, analysis, and thought experiments; published data and solicited observations." The first of these rests upon the skill and experience of the personnel involved, the second has already been mentioned and is treated in detail in Report 73-13, Vol. 6, and the third is readily available in the literature (Telecommunications, 1972; Pyes, 1972) or by solicitation of vendors.

From the nature of the CATV system, one design objective appears clear: the system will be expected to function very reliably in a "real-time" situation. As also noted in Report 73-13, Vol. 6, this requires that the following three capabilities exist: (a) efficient scheduling and processing of time-critical processes (Serlin, 1972); (b) real-time fault detection (Allen and Yau, 1972), correction, and recovery; and (c) some measure of backup or redundancy. The third requirement above can at least be handled by providing some duplication of equipment. It is not clear, however, that the first two items have proceeded far enough beyond the initial research phase to yet provide the needed answers. Beyond these considerations, however, it appears (Waks and Kronenberg, 1972; Ossanna, 1972) that sufficiently, sophisticated, mini-computer configurations exist to be able to handle the tasks assigned. In addition the cost of these systems (Telecommunications, 1972; Hillegass, 1972; Theis, 1972; Waks and Kronenberg, 1972; Ossanna, 1972) is dropping rapidly. From the equipment configuration of the four existing systems described above and the existing literature noted above, a statistical analysis of the costs make it appear that initially an investment for hardware of approximately $70,000 (± $20,000) is involved. This can be expected to decrease rapidly with time for two reasons. First, technological advances will bring the basic hardware costs down. Second, as the necessary configuration for CATV head-end processing evolves and becomes clear, less general purpose equipment and software will be necessary. That is, CATV techniques will evolve and become "state of the art" and then more or less "off the shelf." This latter point is discussed in more detail in Report 73-13, Vol. 6. This point combined with the projected revenues (Oettinger, 1971; Walker, 1972; LaBlanc, 1972) for CATV, makes the projected computer systems well within reasonable economic bounds.

Another real possibility that should be considered for future systems is that of voice, rather than digital, response by the user. This would not only provide two-way interactive voice capability, but coupled with recent advances in automatic speech recognition and synthesis by computers (Datamation, 1972b; Sales Brochure, 1972b; Computer Design, 1972; Newell, et al., 1971), it could provide a better and more readily acceptable machine interface (Meadow, 1970).

In summary, it appears that the vast majority of the needed hardware technology is now or will be available when needed. As pointed out, however, a few pertinent questions need to be answered before the design phase can begin. Additionally, the areas of real-time scheduling of time-critical processes and fault detection, correction, and recovered need further research and development.

3.3 The Software Problem

In this general area there appears to be a semantic difficulty in that two different, although related, uses of the word "software" appear. One finds it in the context of (1) the types of services available (channel selection, computer-assisted instruction, remote shopping, polling, and so on), as well as, (2) the computer programs necessary to provide the above and also more elementary services. We shall refer to the latter as software and the former as services.

As Baer (1971) very correctly points out the "software ultimately is likely to be as critical as terminal hardware in determining the cost and feasibility of two-way subscriber services". He also makes note of the general categories of this software that will need to be available. But more particularly, identified below are four levels of software that need to be provided in a functioning system (see Figure 7):

Level	Name	Function
0	Monitor	Contains all device dependent drivers, communication packages, scheduling and resource allocation sub-systems.
1	Executive	Contains the "communications interface" between the computer and the user--the command recognizer and process initiator.
2	Problem Oriented Languages (POL)	Contains the software in which the services are programmed--for the construction of applications software.
3	Applications Software (AS)	Contains the programs actually providing for the va.ious services.

The above breakdown can be found explicitly in some sources and at least implicitly in Watson (1970) and Meadow (1970. These latter two references also provide some more detailed insight which should be valuable to the constructor of such systems, and hence, they, or references like them, will need to be consulted when such construction begins. It should be noted that the above breakdown is not unique, and other possible organizations exist (Watson, 1970). These should be investigated to see if they are better suited for the CATV environment. The above four levels of software are essentially those required of any good general-purpose, time-sharing system, but we desire to discuss them within the framework of CATV. First, it should be noted (and as will be discussed in Section 4.1) that all of these need not reside in the same machine. The level 0 software will have to reside in each machine to some extent. However, because of the large number of users expected on such CATV systems, two or more computers may be required.

While one machine handles all direct terminal communications and some degree of command recognition, the other machines can handle the more sophisticated requests requiring more computer resources. The reasons for this will be discussed later.

The required basic level 0 (monitor) software exists now to some extent, but being device-dependent, it is limited to particular devices. The existence and utility of this software is somewhat "spotty" for certain devices (e.g., communications) and for some manufacturers. The supporting software (e.g., resource allocators) and the controlling software that tie this level together do not as yet generally exist for minicomputers and may have to be specially written for the CATV application.

The level 1 (executive) software that exists for the present time-sharing systems forms an instructive example, but by no means can be expected to suffice for CATV systems. The reasons for this are:

1. A less sophisticated audience of users (in the sense of the lack of computer orientation of the users),
2. a vastly different type of service to be provided, and
3. the need (in connection with 1) for a much more "human engineered" and easy-to-ues, conversational command recognizer.

Watson (1970) and Meadow (1970) provide guides to the pertinent literature presently available in the field, but for CATV, this is essentially untouched territory which will require much research and development. It should be noted, however, (as time-sharing systems have shown) that a lack of sophistication on the part of both the system and user can often be overcome if the system is straight forward and if good operations manuals are available to the user.

The level 2 (POL) software does not exist at all except for the possibility of some Computer-Assisted-Instruction course construction programs. Generally little mention of this area of software is found within CATV literature. Although much consideration has been given to the construction of services (level 3 programs), few have bothered to wonder how and in what language they should be constructed. In the standard computer field, however, this is a much discussed subject (Waks and Kronenberg, 1972; Osanna, 1972; Sammet, 1972; Thompson and Dostert, 1972). There are many reasons for the existence of such languages. As Sammet (1972) notes, two of these reasons are:

1. The inclusion of special functional capabilities and
2. a need in application (or problem) oriented languages for a specialized vocabulary or professional jargon in order to make the communication of ideas easier.

Thompson and Dostert (1972) also point out that these languages to some extent provide to the computer operating system designer or applications programmer what the "breadboard" does to the circuit designer. It is easy to foresee the need for all of these within CATV systems, and hence the need for this level of software in the CATV industry.

The level 3 (Applications) software in some sense presently exists in two ways:

1. People (Mason, et al., 1972; Baer, 1971; MITRE, 1972; Setten, 1971a) have foreseen the need for various types of services.
2. A number of the demonstration systems already have some such software working, although it is not, in general, written in a level 2 system (MITRE, 1972; Volk, 1971; Setten, 1971a; Setten, 1971b; Callais and Durfee, 1972; Callais, 1972; Vivian, 1972).

Some general considerations concerning the users when designing these levels of software should be kept in mind (Vogt, 1970):

1. Access control to varying levels and services of the system must be rigidly enforced.
2. The systems used must not involve any great loss of efficiency or economy.
3. The cost of illegally accessing information or services within the system must be much greater than the benefits expected from the violations.
4. The subscribers must have access to as much information regarding them as possible, have rights of appeal, and have some control over who can gain access to such records.
5. And most importantly, the system must be easily usable.

These considerations are not trivial to include in any given implementation, and hence, we readily agree with the remark by Baer (1971) with which we opened this sub-section.

Additionally, Baer (1971) remarks:

"Technologists and managers alike often tend to underestimate the non-hardware costs of providing services made feasible by a new technology. In this respect, the development of cable communication services may be analogous to the development of computer time-sharing services in the 1960's. At first, computer system designers consistently underestimated the difficulty and cost of creating system software for time sharing. Then, once time-sharing systems were up and running, users found that applications software represented an increasing fraction of the total computing cost.... Following a similar argument, one would expect the software costs of two-way cable communications services to predominate as use of the two-way network increases."

Most probably time will indeed confirm Baer's predictions. For this reason, we should attempt to learn from the experience of time-sharing systems designers -- especially because of the very similar nature of the requirements for CATV system software.

In summary, then, it appears that the software problem (along with the design of the subscriber terminal) will have the most visible consequences to the subscribers and will require very careful design and implementation. Although present time-sharing systems can provide some guidance, there are enough differences between time-sharing and CATV that an essentially new and independent software development effort will have to be mounted, as little such software exists today in any general-purpose form. From past time-sharing experience we can therefore predict that it will be a difficult and costly endeavour, requiring an intensive research and development effort.

3.4 Computer-to-Computer Communication

In all of the discussion thus far in this section, we have only considered the computer-hardware, -software, and -communication problems within one CATV net (see Fig. 8). Figure 8 also displays the various interconnections: (1) subscriber terminal A to network, (2) network to head-end processor, (3) head-end processor to network, and (4) network to subscriber terminal B. At each of these points some protocol for exchange of information must be established so that each is able to interface with the other. In this case the problems of hardware, software, and communication protocol standardization are not difficult since the net is designed as an integrated whole.

Consider now the configuration illustrated in Figure 9, or even the generalization of this to the establishment of a "conference-like" connection of several subscriber terminals. Here problems arise due to differences in the hardware, software, and communication protocols

of the various CATV nets which are linked together through their head-ends. How, for example, does subscriber A send a message of, say 256 characters (standard message size for A's terminal) to subscriber B's terminal which is only capable of, say, 96 characters per message. Since the home terminal is to be as simple and inexpensive as possible, then obviously one (or both) of the head-end processors must worry about this problem. This requires careful, general software design. Imagine now the added complexity of the "conference-like" connection of a number of non-compatible terminals. The question again arises as to just where the necessary software transformations needed to ensure compatibility must be made in order to allow for complete generality in connection.

This problem also arises in the ARPA computer network (Carr, et al., 1970; Crocker, et al., 1972). The terminal design problem is likewise considered (Roberts, 1972). It appears, on the basis of the ARPA net experience and the fact that no high degree of standardization will be achieved in CATV network development, that the only hope for inter-network communication standardization lies in the definition of a (software implemented) communication protocol. This protocol consists of a standard format for transmission of messages between networks. It will be formatted and encoded by the head-end to which the originating terminal is attached and decoded by the receiving head-end. It should contain some form of information for giving the "addresses" of both the source and destination terminal, information on the buffer length and other characteristics of the originating terminal, and some form of error detection and/or correction. Design and simulation of the rest of the network probably will reveal other items of information that need to be added to the protocol in order to remove any visibility of differences in hardware, software, and communications protocol between the networks.

The above example should not be construed to imply that it describes the only area of difficulty in computer-to-computer or terminal-to-terminal communication. It is meant only as an illustrative example. Depending upon the final degree of standardization of the communication, computer, and terminal hardware and software techniques, the problem may be more serious or may disappear completely. One must also consider the problems arising in the compatability of the analog signals.

In summary, interconnection of CATV networks posts a requirement for some standardized communication protocol. The experience of the ARPA computer network should suffice in this design provided it is coupled with the overall network design and simulation.

4. SYSTEM LIMITATIONS ON COMPUTER AND SOFTWARE REQUIREMENTS

Limitations due to noise, interference and bandwidth are interrelated and closely related to:

1. The spectrum allocation,
2. the forms of modulation used, and
3. the modem design.

All of the above can, to a large extent, be considered independent to the computer. These three do interact so as to determine the transmission rate which the computer is expected to maintain, but generally speaking from the design parameters of typical CATV systems in the literature (Callais and Durfee, 1972; Callais, 1972; Vivian, 1972; MITRE, 1972; Volk, 1971; Setten, 1971a; Setten, 1971b) and the state of the art in computer speed, (Telecommunications, 1972; Hillegass, 1972; Theis, 1972) it does not appear that there should be any problem meeting and surpassing the required speeds. This is considered more carefully in the next section. One other area does intersect with these considerations--the achievement of acceptable bit error rates on the digital information. The hardware rates can be considerably improved by having the computer include sophisticated message protocols and error detection and/or correction. Aside from these considerations, the limitations referred to above seem to have little impact upon the hardware and software requirements of the computer. As mentioned earlier, the computer can also process the video signals in order to maintain picture quality.

4.1 Size of Service Area and Number of Customers

It is presently possible to have access and effectively and economically communicate with computers nationwide via standard telephone circuits and various computer networks (Farber, 1972 and

Tymes, 1971), as well as, worldwide via TYMNET (Tymes, 1971) and soon via the ARPA net. Therefore, it appears that there is no intrinsic computer hardware or software limitation. This parameter will be mainly determined by the design and implementation of the distribution network as long as the number of users in each service area can be limited to assure adequate processing power per user (see below).

Again here we must consider that signals degrade with distance and cascaded amplifiers. The computer implemented signal processing could help to expand the physical size of the service area. However, this seems to imply some sort of distribution of the computational power along the network.

A limitation does exist for the number of customers supportable by the state-of-the-art computer hardware and software. Existing time-sharing systems (Scherr, 1967) typically handle 40-250 terminals (see Fig. 10), and current projections only envision systems capable of handling at most roughly 1000 terminals in the foreseeable future. However, time-sharing systems have a large majority of their terminals active at any given time, and services requested are so sophisticated that each consumes a large amount of the system resources. Such a workload cannot be envisioned for a CATV system where, even during peak evening hours, only a small fraction of the subscribers will be requesting services at any given instant and then, in all probability, only very simple ones. The more sophisticated tasks would be expected to occur only in very small numbers during any given period of time and probably not during prime entertainment hours. If this is the case (as hopefully will be confirmed by experimental systems), then techniques, which are similar to the telephone companies use of only 24 switches per block of 100 phones, could be used. Such knowledge coupled with sophisticated simulation could be expected to yield optimal or nearly

optimal processing configurations and software strategies. In any event, low probability peaks could be handled by "blocking" of the request as in present day phone systems. and engineered for a 1%-2% blocking probability. It should be noted that generally such "blocking" of requests has a bad psychological effect on the user at his terminal. This is confirmed by experience with time-sharing systems, as well as, the telephone system. On the other hand, usage does show, that the number of requests coupled with the amount of resources requested runs at higher levels than expected, then one could switch to multi-computer systems as described above.

In summary, it appears that the present and projected technology should allow handling of the necessary workloads. The only problem that may arise is the cost of using such brute force techniques to solve these problems may prove economically prohibitive to the viability of a commercial enterprise. Thus, we find the need underscored for careful design and simulation of the entire network and its associated software.

5. PRIVACY AND SECURITY

The services that have been proposed (Jurgen, 1971; Mason, et al., 1972; MITRE, 1972; Setten, 1971a; and Baer, 1971) for future CATV systems raise the spectre of invasion of privacy. The issue of individual privacy is a matter of increasing concern to our nation, as is evidenced by concern in all areas of the nation's press (Datamation, 1972a; Fano, 1970; Vogt, 1970; Kraning, 1970; and Greenberger, 1971). The U. S. Congress was early to recognize this problem and has held continuing hearings on the issues involved (U. S. Congress, 1966, 1967, and 1968). The Executive Branch has also expressed concern. For example, the U. S. Office of Science and Technology (Privacy and Behavioral Research, 1967) has studied the problem particularly with regard to behavioral research. The findings also have application in this instance.

The Office of Science and Technology found, to their dismay, that there was gross disregard for human values as indicated by the advocacy or actual practice of eavesdropping, the use of lie detection devices without clear justification, and the frequent willingness to institute surveillance procedures to handle the problems of a small proportion of the population at the risk of eroding the rights and the quality of life for the very large majority. The study also notes, but does not attempt to review in detail, the wide variety of mechanical and electronic devices which make such intrusion possible. To this list of devices can now be added CATV systems--unless proper precautions are taken.

Having established that there is a definite need to consider measures to ensure privacy and security, one question clearly needs to be asked: "What are privacy and security, and how are they maintained?" Conway et al. (1972) states that information privacy involves issues of

law, ethics, and judgment, and information security involves questions of the means of ensuring privacy. Specifically, privacy involves a person's "right to privacy", while security involves the means of maintaining this privacy. The OST study devotes much consideration to the nature of privacy, but essentially notes that "the right to privacy is the right of the individual to decide for himself how much he will share with others his thoughts, his feelings, and the facts of his personal life--it is a right that is essential to insure dignity and freedom of self-determination." This is a statement with which few would argue, but it is interesting to note, as Hoffman (1969) does, that "we often forget that no 'right to privacy' similar to the 'right to freedom of speech' or the 'right to vote', exists in the Constitution...." The amount of privacy to which an individual is entitled and the situations in which that privacy may be violated vary according to the whim of a particular court or legislative body (Westin, 1967). Excellent surveys on this subject can be found in an article by Prosser (1960), and in books by Westin (1967, 1972). The topic of the nature and amount of privacy to which a person is entitled is beyond the scope of this report. It is the responsibility of the judicial and legislative process. Our intent is only to point out that consideration must be given to the need for and nature of privacy in CATV systems. It should be clear from the foregoing that the CATV system designer must allow for the maintenance of whatever degree of privacy is legally determined to be the right of the individual. Since this is at present a very subjective and variable quantity, it imposes the additional requirement of system flexibility upon the designer.

We next need to consider the "nature of the beast" within the confines of a CATV system. Baer (1971) points out that there are basically two separate issues to be dealt with in CATV systems: (1) how

to maintain signalling privacy, and (2) how to maintain data privacy. Basically the first problem is one of eavesdropping, wire tapping, or tampering with the addressing hardware of the system and/or user terminal in order to obtain information not intended for unauthorized individuals or to use the subscriber terminal to intrude upon the privacy of its users. The first topic has been considered by Baer (1971) and Mason (1972) as well as others.

In this section we will consider only the second problem, which is complementary to the first problem. It is an attempt to have the system transmit information to an unauthorized terminal or person. This basically involves an attempt by an individual or individuals to thwart the security measures built into the system. It is the inevitable extension of the common pastime of computer programmers to try to "crash," outwit, or confuse a computer's operating system (hardware and software). Because of the success at nearly every computer installation of a small cadre of relatively clever programmers in accomplishing this goal, it is not a question to be taken lightly. Weinberg (1971) has more to say on this and related topics, but suffice it to say that the probability is high that similar attempts will be made to "crash", outwit, and otherwise thwart the computer operating systems in CATV. Also it must be anticipated that a number of these attempts will not be innocent play but rather, will involve definite attempts at invasion of privacy, fraud, and other "crimes of property" and "crimes of slander."

Since the topic of this section basically involves "computers and privacy", and since a vast literature on this subject has developed within the computer field while within CATV circles not much has yet been done on this topic, we will naturally lean on the existing literature in the computer field. Hoffman (1969) gives a very interesting and exhaustive survey of the problem and furnishes a complete annotated bibliography. He

points out that there can be no question of the grave concern over the effects that centralized data banks and information systems will have upon the lives of all individuals within our society.

Criticisms could be leveled against CATV systems as they evolve as essentially an access extension of such information and data bank systems. As Westin (1967) notes, "The true focal point is the direct challenge to the discipline and conduct of man who is the designer and user of the data system." Comber (1969) points out that this is not only a technical or system design problem, but also a personnel and administrative problem. Comber then goes on to discuss the management structure needed to help ensure this. In summary, he notes that the human factor is predominant and that one must allow for (1) establishment of personnel standards, (2) training, (3) accountability, (4) strong disciplinary structure, (5) limitation of data access, (6) an individual's right to information pertaining to him, (7) procedures to provide for the challenge to and correction of information within the system, and (8) a realistic data purge policy. So much for the "people side" of the pro-problem.

Hoffman (1969) also gives an excellent survey of the technical aspects of such "secure systems". He notes the complete inadequacy of the current practice of using only "passwords" to provide protection, and suggests a system of passwords coupled with "threat monitoring." The latter technique essentially logs all incorrect password responses by a user. Though one would hope for a better method, in CATV systems this technique combined with the system obtaining and recording the terminal address for each incorrect answer could provide a means of monitoring for unauthorized activity. However, if CATV systems become very large the volume of this information could grow prohibitive and prevent checking and detection. Basically recent attempts (Hoffman,

1971; Lampson, 1969; Collmeyer, 1971; and Conway, 1972) have involved (1) allowing individual items (words, sentences, paragraphs, etc.) in a collected data base to have assigned to each its own level of security rather than in a "block," and (2) to make access control more flexible in that at "access time" the decision to grant or deny access is made based upon information which is data, terminal, time, and user-response dependent. In particular some very clever low-overhead techniques are currently being developed within commercial information systems (Potts and Emmer, 1972). The details of these techniques are not to be discussed. Suffice it to say that (1) research on privacy is presently going on, (2) techniques exist for assuring some measure of privacy and of monitoring for compliance, and (3) these techniques should be applicable to the computer operating systems which will exist in future CATV systems.

It should be noted that in all probability there is no guarantee of 100% security. A reasonable view of this probability can be obtained from another paper by Hoffman and Miller (1970). They illustrate that with enough work and sufficient additional non-classified information it is possible to obtain a personal dossier from even a statistical data bank--one where only statistical summaries are permitted or in the extreme where all identifying information has been removed. Then he reproposes that a "threat monitoring" technique, while not foolproof gives substantial additional protection.

In summary, the need for privacy is real, the threat to it is equally real, and the security techniques to ensure some percentage level of privacy exist (Linde, 1969; Weissman, 1969; Skatrud, 1969). The CATV designer needs to (1) deduce the level of privacy that various security techniques provide, (2) determine the acceptable level of failure (or the level of privacy required), and (3) choose the system most closely

satisfying his needs, if it exists, or fund further research based upon his requirements, if it does not exist. The real problem appears to be the determination of the acceptable level of failure. In any event, further research and development in the area seems necessary.

6. PERFORMANCE STANDARDS

6.1 Industry Standards

The service initially offered on cable television systems was simple delivery to subscribers of off-the-air television broadcast signals. The signals were delivered in the standard broadcast signal format so that they could be received by the subscriber on a conventional television broadcast receiver. To this initial service there has been added delivery of a limited amount of locally originated programming. To provide compatibility with the initial service, the local programming also is delivered in the standard broadcast signal format. Thus there has been no incentive or necessity for the new industry to develop a standardization program related to television signal generation or signal format. The industry has simply borrowed from the television broadcast industry.

Standards of subscriber terminal signal level were fixed, within rather broad limits, by the intent that the subscriber terminal should be a conventional broadcast television receiver. Choice of the cable system output impedance at the subscriber terminal was subject to the same consideration. Again, there was little incentive for the cable industry to engage in significant standards development in this area, except for purposes of guidance to distribution equipment manufacturers. The National Cable Television Association (NCTA) did adopt a standard for subscriber visual carrier level (NCTA-001-0363). It has since been withdrawn (perhaps in favor of the new FCC technical standard).

In the area of television signal processing and distribution, the cable industry has had to develop new concepts and a line of hardware to implement these concepts. Only in this instance does there seem to have been significant activity by the cable industry in the development

of standards. Further standards have been adopted by the NCTA for graphic symbols to be used on CATV systems layout drawings (NCTA-003-0668), CATV amplifier distortion characteristics (NCTA-002-0267), and noise level in cable systems (NCTA-005-0669). The last has been incorporated by reference into the FCC technical standards (Part 76, Rules and Regulations of the FCC).

The standard on system noise level does not specify acceptable noise levels or signal-to-noise ratios. Rather, it specifies procedures for measurement of system noise level.

6.2 Federal Communications Commission Standards

Rules and regulations governing the Cable Television Service are set out in Part 76 of the Rules and Regulations of the Federal Communications Commission. This part was added to the rules and regulations by an order adopted February 2, 1972.

In Paragraph 76.5, Subpart A of Part 76, four classes of cable television channel are defined as follows:

> Class I Cable television channel: A signalling path provided by a cable television system to relay to subscriber terminals television broadcast programs that are received off-the-air or are obtained by microwave or by direct connection to a television broadcast station.
>
> Class II Cable television channel: A signalling path provided by a cable television system to deliver to subscriber terminals television signals that are intended for reception by a television broadcast receiver without the use of an auxilliary decoding device and which signals are not involved in a broadcast transmission path.

Class III Cable television channel: A signalling path provided by a cable television system to deliver to subscriber terminals signals that are intended for reception by equipment other than a television broadcast receiver or by a television broadcast receiver only when used with auxiliary decoding equipment.

Class IV Cable television channel: A signalling path provided by a cable television system to transmit signals of any type from a subscriber terminal to another point in the cable television system.

The same paragraph contains additional definitions of terms related to cable television systems and the cable television service.

These categories tend to be confusing. A lucid description was recently given by Sidney Lines of the FCC (Lines, 1972). We reproduce his description in the interest of alleviating this confusion.

> "Briefly, Class I cable television channels are channels which carry off-air broadcast television signals. Class II cable television channels are those channels carrying locally originated programs---"cablecasting." Class III cable television channels are those devoted to other forms of downstream communication such as facsimile, encoded TV, private or closed circuit TV, digital or analog data, off-air FM or AM signals. Class IV channels are those which carry upstream or "return" communications. At this time, we can imagine only some of the kinds of signals upstream communications will involve in the future. I contemplate that the future may see the Commission setting up additional channel categories."

Subpart K of Part 76, entitled Technical Standards, delineates the technical performance criteria which systems in the Cable Television Service are required to satisfy. At this date standards are promulgated only for Class I cable television channels. No reference is made to

standards for other services that might be offered on a broadband communication network. Subpart K treats performance testing, technical standards, measurements and interference topics.

The paragraph on performance tests (76. 601) embodies several provisions. It lays on the system operator the responsibility for insuring that the system meets the performance requirements stated in Subpart K, and for being prepared to give evidence that compliance is, in fact, realized. The paragraph calls for a minimum schedule of proof-of-performance testing and a requirement for maintenance and preservation of records of test results. The objective of this paragraph is to insure that system operation is in compliance with the applicable rules and that service to subscribers is at an acceptable level of quality.

Paragraph 76. 605 is entitled Technical Standards (same as the title of Subpart K, but not to be confused with the totality of that subpart). The standards concern only the characteristics of Class I cable television channels as measured at any subscriber terminal. Standards are specified for: channel frequency boundaries, signal frequency format within channels, visual signal level, aural signal level, channel frequency response, the ratio of visual signal level to system noise and interference, subscriber terminal isolation, and radiation from a cable television system.

Paragraph 76. 709, entitled Measurements, discusses conditions and procedures for making the measurements required for proof of performance. Procedures are specified in rudimentary form rather than in great detail. In the procedure for measurement of system noise, reference is made to NCTA Standard 005-0669; permission is given to make the measurements according to this standard.

It seems clear that the intent of the technical standards is two-fold. One function is to establish interface parameters at the subscriber

terminal adequate to ensure compatibility of broadcast television receivers and cable transmission devices. The other function is to assure that signal degradation in the cable system does not exceed acceptable limits. The standards do not specify overall signal quality, but only an upper limit on channel degradation.

Paragraphs 76.613 and 76.617 of Subpart K place on the cable system operator the responsibility for remedying inter-system interference caused to other services by operation of the cable system and intra-system interference generated by receivers on the system and introduced into the system at the interconnection point.

6.3 The Need for Additional Standards

The cable television service is in many aspects in its infancy. Standards for the service are, not surprisingly, in the same state. Those which exist are the ones which are essential to launching the industry. As the industry grows, and as the variety of service offerings expands, a program of standards development will be required.

For some time to come there would seem to be substantial overlap of the cable industry with the television broadcast and television receiver industries. The most active area for standards activity by the cable industry is likely to be in signal processing and signal distribution. Development is needed both in operational standards to facilitate equipment and interconnect compatibility and in performance standards to specify and assure acceptable signal quality.

As other services are offered on the cable systems, additional areas of standardization will begin to open up. Early openings can be expected in the interactive services, perhaps initially in subscriber program selection and in subscriber response within teaching or discussion situations. These services will require standards for services utilizing signals in Class IV cable television channels (FCC Rules and Regulations, Part 76, Subpart A, Paragraph 76.5). No standards have yet been promulgated for such services, signals or channels.

Inevitably there will develop an overlap of the cable industry with the data processing industry. This may begin with the use of minicomputers in head-ends for system management and be extended to information retrival services. Signal format and transmission standards for these functions and services will have to be established.

Signals on cable systems will occupy portions of the spectrum also assigned to other services for which transmission is in the radiative

mode. Cable systems are likely to develop extensive distribution networks. The distribution networks are, to a greater or lesser degree, vulnerable to faulting due to deterioration or damage. For example, faults in a cable sheath will lead to radiation. Although the signal power levels on the cables will be relatively low, the extensive nature of the distribution networks makes the possibility of radiative interference to other services significant.

It seems probable that a more extensive series of performance standards should be developed to define excessive radiation more thoroughly, to assure detection and identification of excessive and interfering radiation and to provide for adequate suppression of radiation. This matter appears to be of special concern for segments of networks in the vicinity of airports or other air traffic corridors. Interference with flight or navigation aids poses an immediate threat to safety of life, particularly in flight conditions which are degraded or dangerous. The Cable Television Advisory Committee (CTAC) established by the FCC is studying these questions.

Any attempt to predict the sequence and timing of the development of new services on cable systems is fraught with risk. It is a highly speculative business beset with a number of intractable factors. This, in itself, is sufficient reason for closely monitoring industry development and tends to identify as early in the process as possible the needs for new and additional standards, as well as, the revision of old standards.

7. HEAD-END MEASUREMENTS

Measurements required at the head-end both from the standpoint of good engineering practice and to meet FCC specifications fall into the six general categories--frequency tolerance, amplitude level, noise, interference, distortion, and phase shift. These are considered below.

The FCC requires that the frequency of the visual carrier shall be 1.25 MHz ± 25 kHz above the lower boundary of the channel. The absolute value of the sound carrier is less critical than its frequency relative to the visual carrier which is specified to be 4.5 MHz ± 1 kHz. These frequencies may be measured by beating a standard signal source with the TV signal and observing the frequency difference with a spectrum analyzer or other suitable receiver. The signal source may be a stable signal generator used with a frequency counter or it may be a frequency synthesizer. With present day crystal oscillators of any but the cheapest sort, it should be no problem obtaining the one part in 10,000 frequency accuracy required.

The FCC requires that the variation of signal strength between adjacent channels to be no more than 3 dB and across the entire span of channels no more than 12 dB. These criteria are important from the standpoint of minimizing the adjacent channel interference at the television receiver. Also it is important from the standpoint of optimizing the operation of the amplifiers in the distribution system. Because the levels of signals entering the head-end will vary, each channel must have an effective gain control system which should be periodically checked with the calibrated field-strength meter at the head-end output. An individual channel which is below the optimum level will cause a degraded picture in that particular channel at the television receiver. If it is much above the optimum level, the line amplifiers will be overloaded, the result of the degradation of all the channels. The level of the

aural signal is required by the FCC to be maintained 13-17 dB below the visual signal level. As the corresponding FCC requirements for broadcasting station are 7-10 dB below the visual carrier, selective attenuation of the aural carrier is normally required in the head-end. The calibrated field-strength meter, with appropriate selectivity characteristics, is the straightforward way to make this measurement.

Noise, interference, and distortion have been discussed in Chapters 4 and 5. The usual technique for measuring noise at the head-end output is to turn off the incoming signal and measure the residual channel by channel. It needs to be recognized that in so doing one does not take account of any noise which may be coming in with the signal i.e., it assumes that the incoming signal has effectively an infinite signal-to-noise ratio. Interference from other channels can be measured in much the same way. One type of test equipment supplies signals on each channel. Since all channels can be filled except one, the vacant channels can be inspected successively one by one, looking at the level of interference in each. Similarly, by modulating all channels but one, it is possible to obtain an indication of intermodulation. Specialized equipment for cross modulation measurement and intermodulation are available, but tend to be expensive.

There is little attention paid to phase shift in the CATV literature, although it can be found in the television literature, such as the early NTSC work (IRE, 1954). Phase shift in the lower frequency components of the luminance signal causes smearing in the picture, while phase shift of the quadrature color signal relative to the color burst causes errors in hue in the resultant picture. In two-way systems where the upstream information is contained in the sub-band, care must be taken that the cross-over filter does not create phase shift problems in the channel 2 downstream signal. There appears to be a lack of both

information and test equipment for the measurement of phase errors in CATV systems. The available test equipment for determining phase errors and similar distortion is rather elaborate and requires experience and some talent for proper use. Careful monitoring of signals with a good color receiver will indicate that trouble exists. The problem then remains to decide where it exists and what its cause. It should be added that as long as off-the-air signals are not brought down to video baseband, there is little reason to expect hue (color phase) problems.

Measurements are discussed, for example, in Taylor and Janes (1970), Penwell (1972), Crusan (1972), and in manufacturers' brochures.

Acknowledgment

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Note: (Translation of computer journal abbreviations)

SJCC = Spring Joint Computer Conference.

FJCC = Fall Joint Computer Conference.

Comm ACM = Communications of the Association for Computing Machinery (1133 Avenue of the Americas, New York, N. Y. 10036)

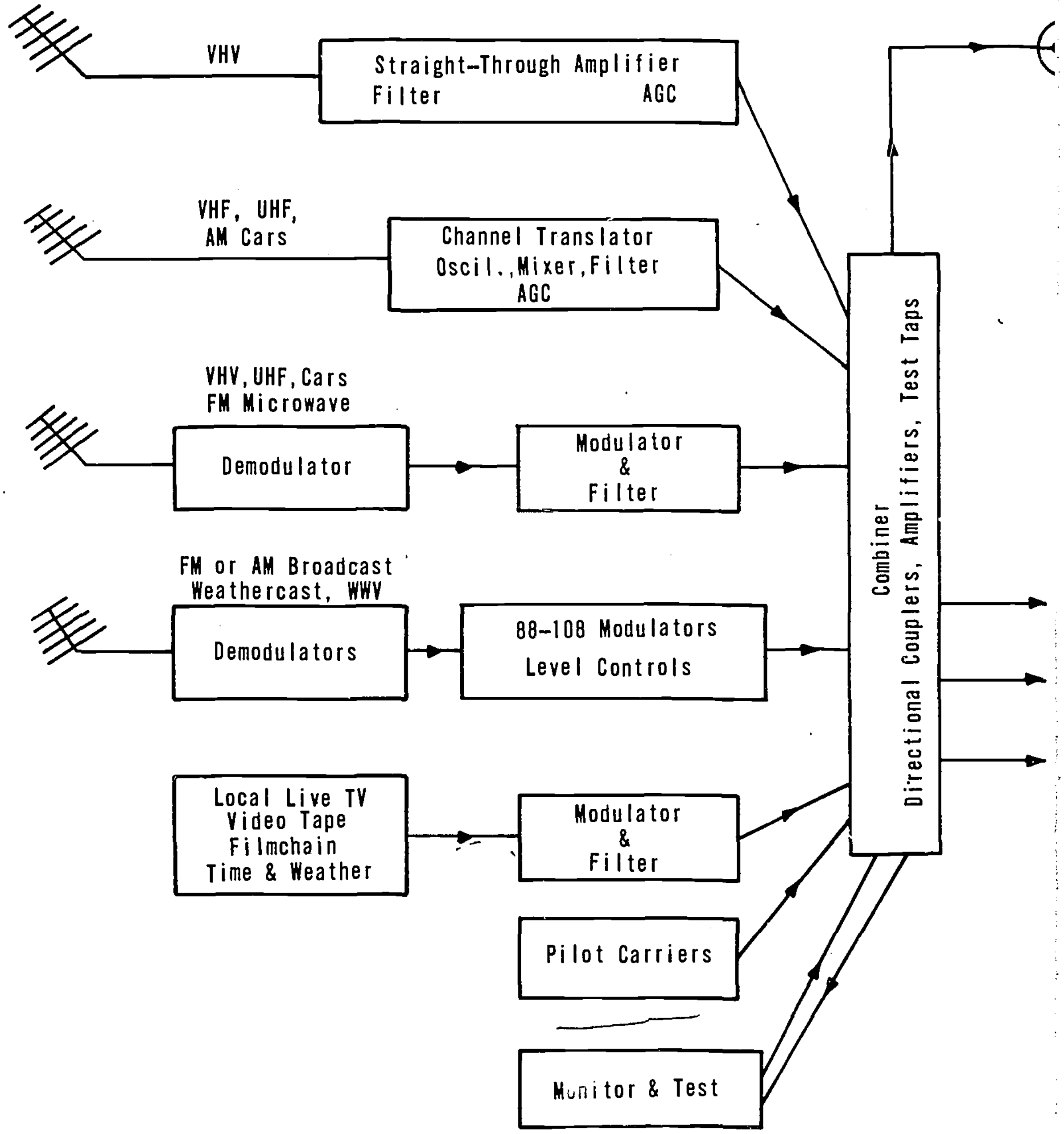


Figure 1. Possible Head-end Operations in One-way Systems.

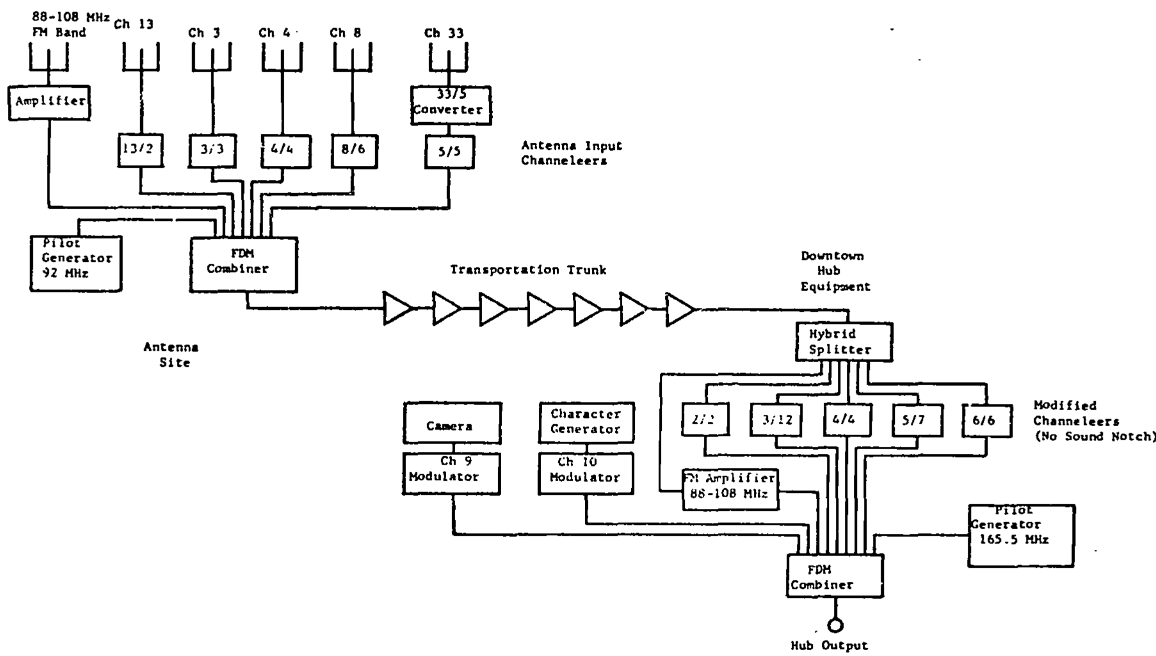


Figure 2. Head-End Configuration Showing Antenna Site Separated from Downtown Hub (Taylor and Janes, 1970). [Reprinted by permission from IEEE.]

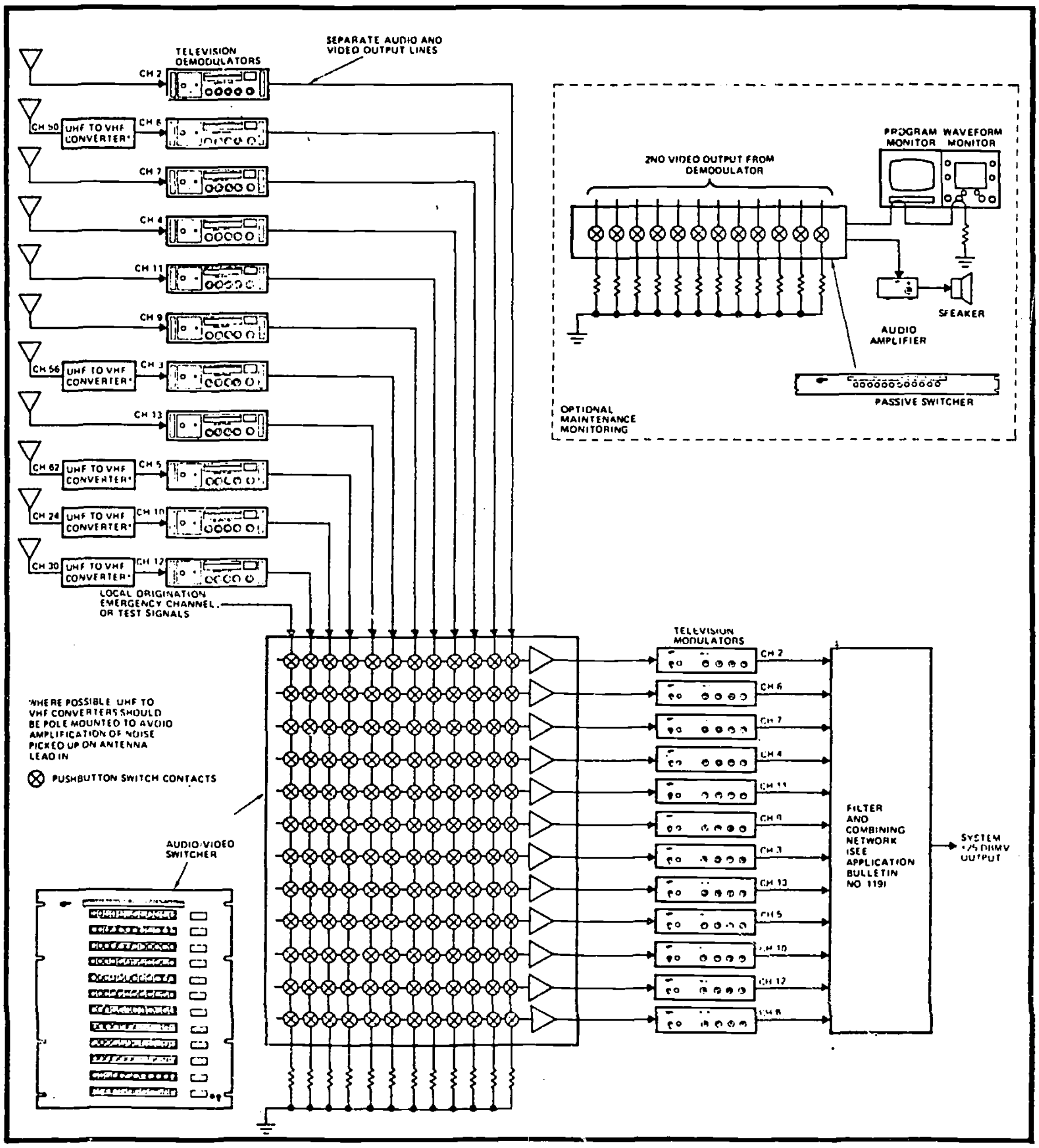


Figure 3. Demodulation-Modulation Head-End (courtesy Dynair).

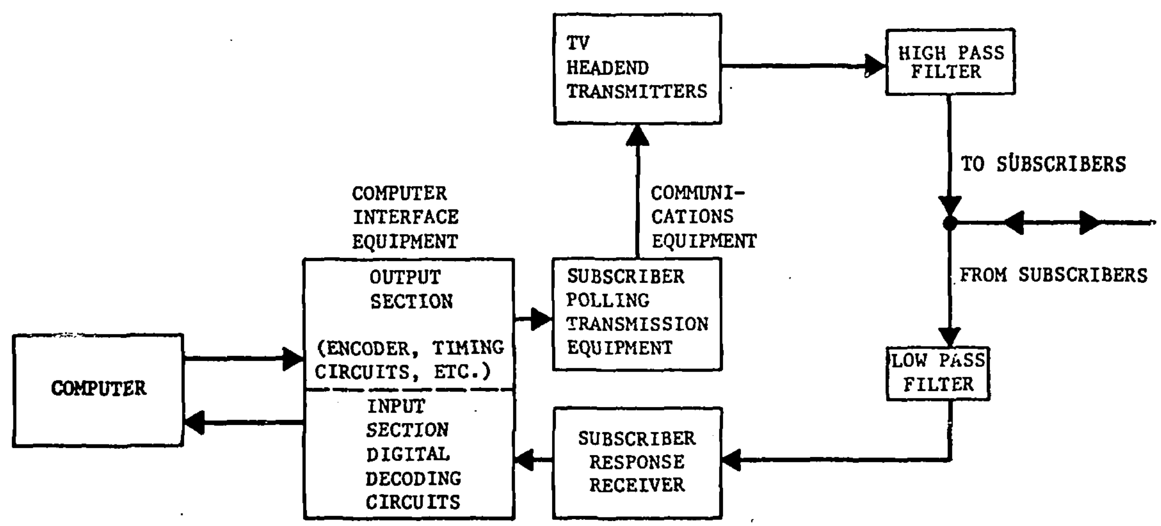


Figure 4. A Head-End in an Interactive System (courtesy MITRE, 1972).

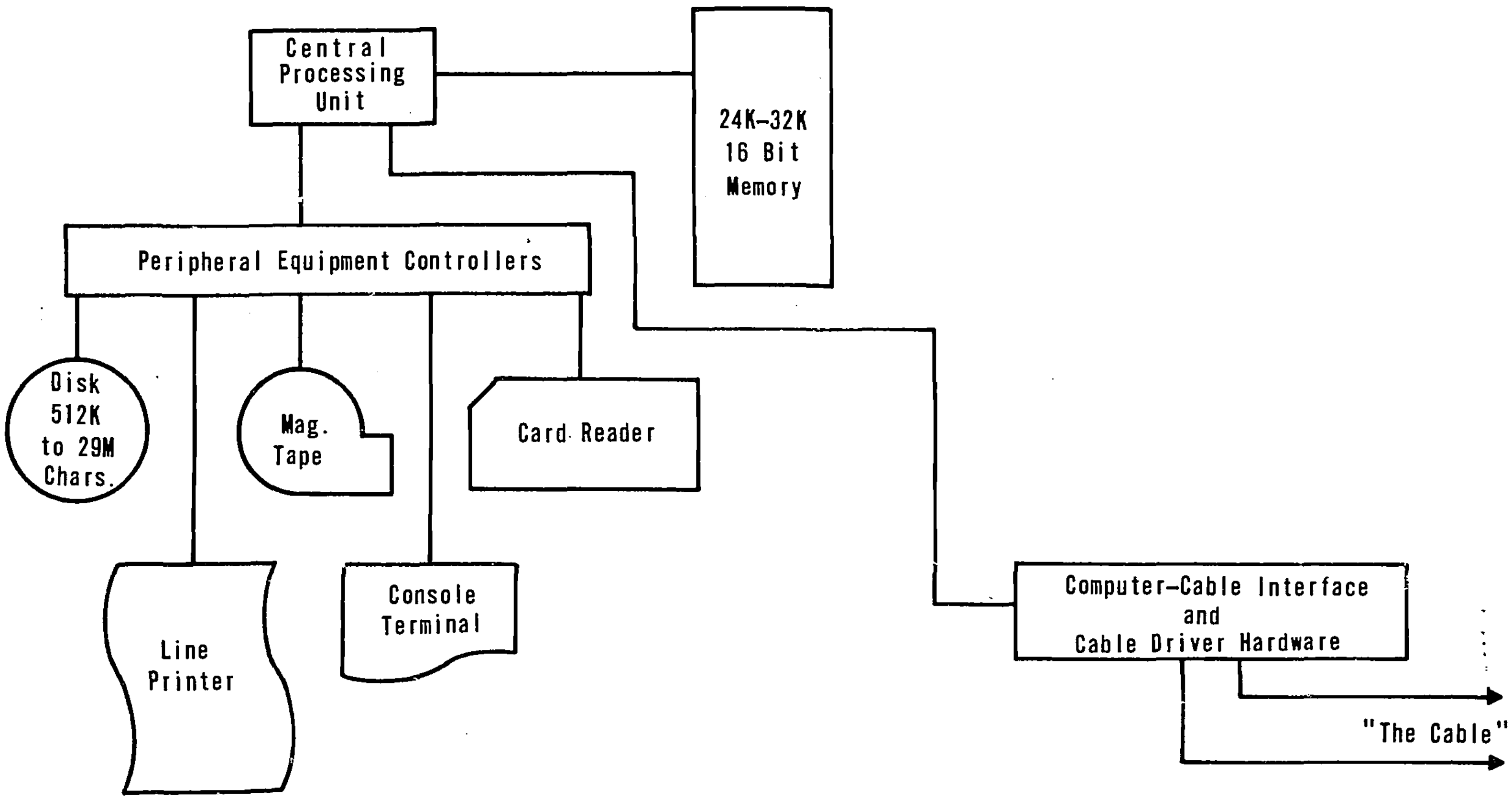
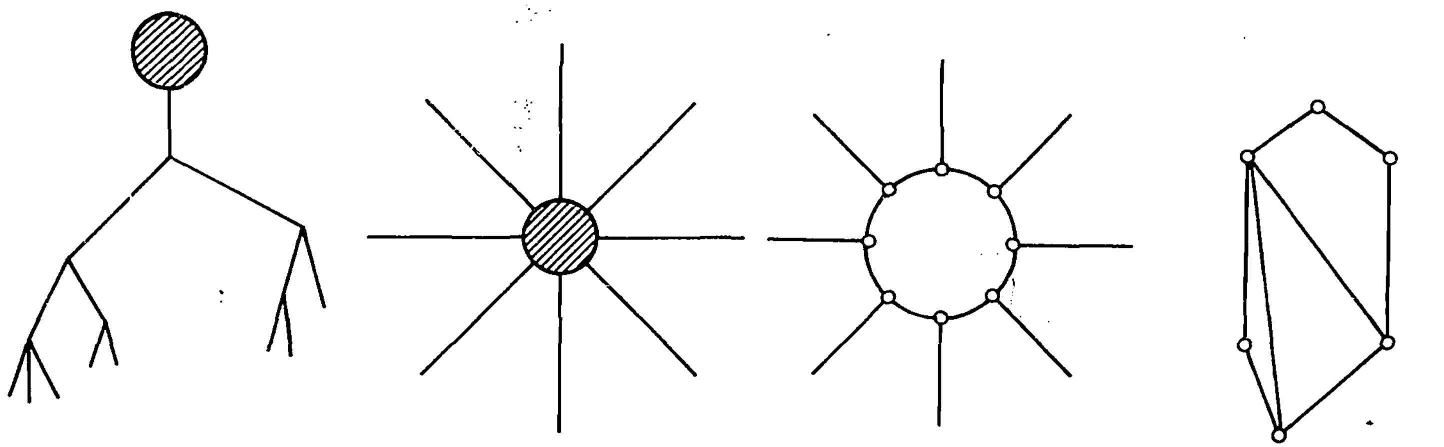


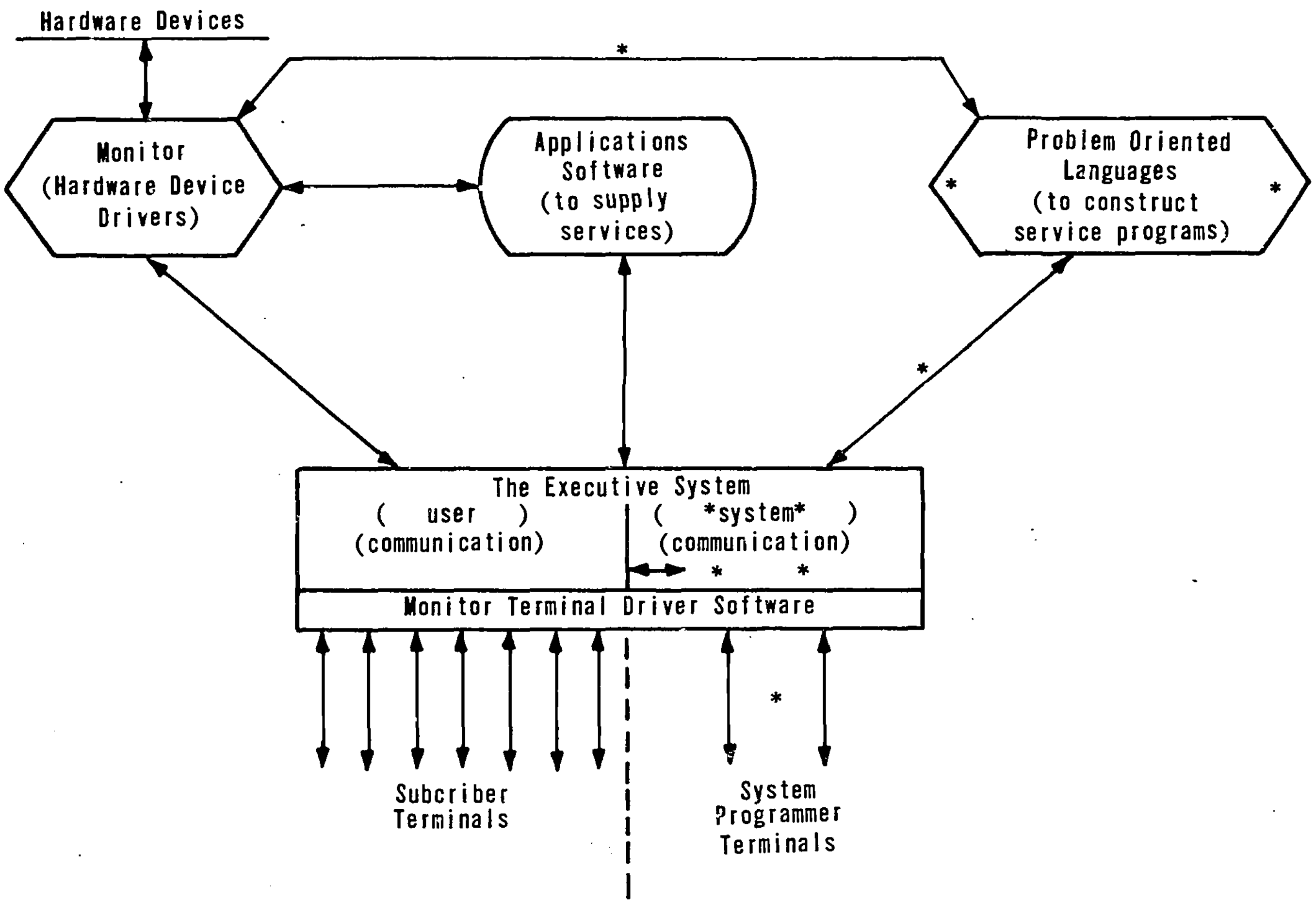
Figure 5. Typical Head-end Computer Subsystem Organization.



(i) Ring (ii) Interconnected

(a) Tree (b) Star (c) Distributed

Figure 6. Some Possible Network Configurations.



* Note: Access to this part of the system limited to systems personnel only!

Figure 7. Typical Computer Software System Configuration.

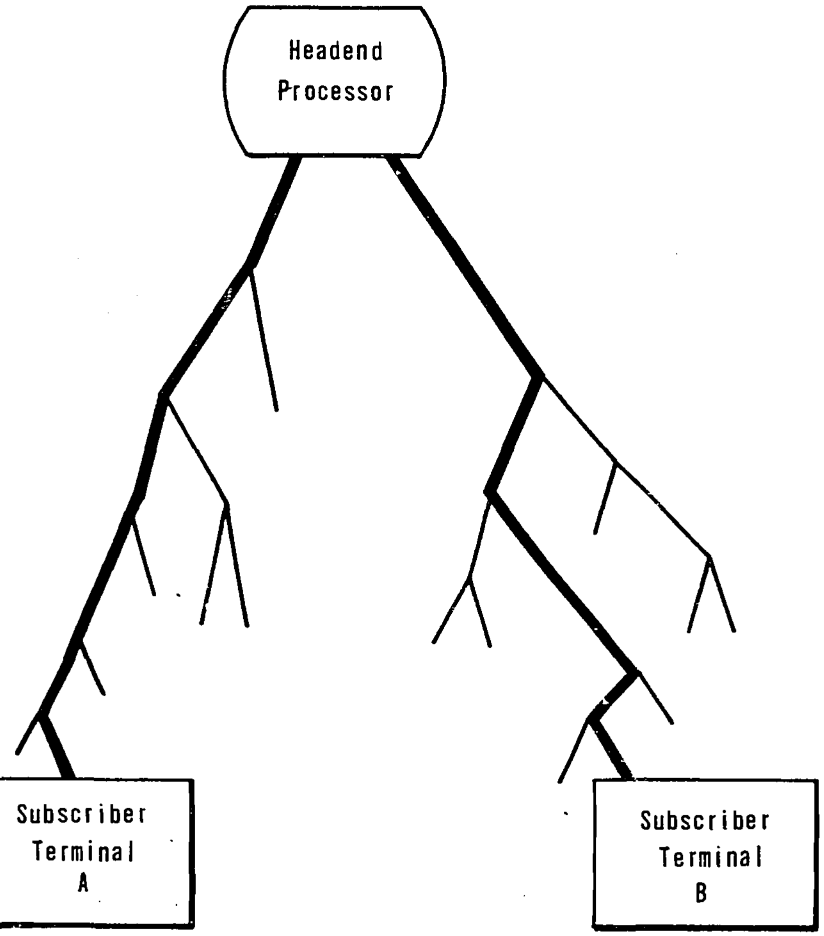


Figure 8. Communication within a Net.

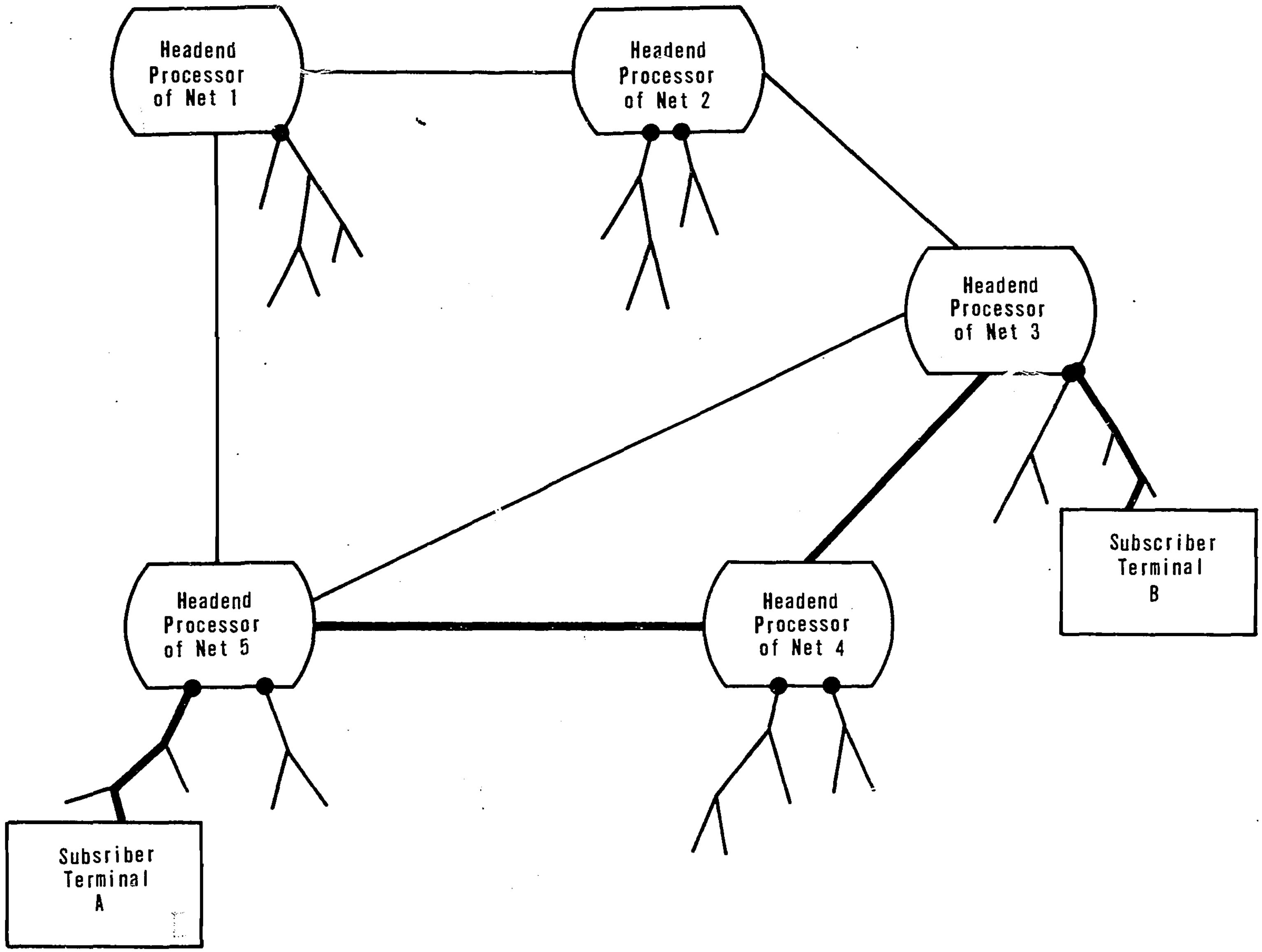


Figure 9. Communication over an Interconnection Network of CATV Networks.

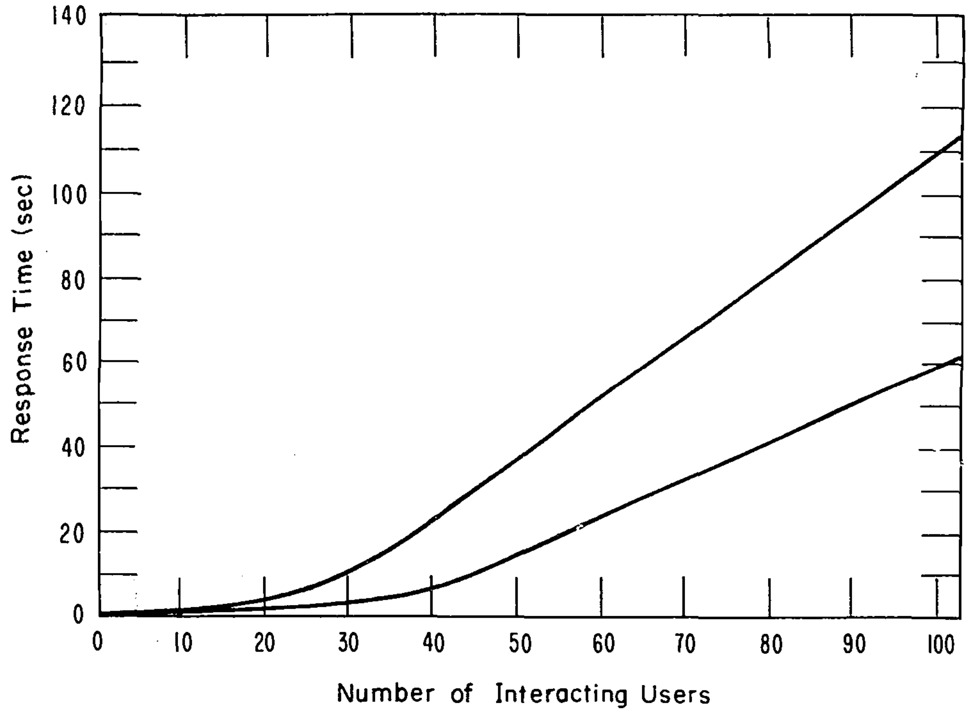


Figure 10. Mean Response Time Versus Number of Interacting Users for Typical Time-sharing Systems (Scherr, 1967) [Reprinted by permission from the MIT Press, Copyright 1967.]

Annex 1

I. THE TELEVISION SIGNAL

INTRODUCTION

An understanding of the broadcast television signal (what it consists of, the compromises involved in its formulation, its history, and current U.S. and international practice) is a necessary ingredient in an assessment of present and proposed teleservices. This annex is attached to this particular report primarily for convenience.

Psychophysical properties of vision are summarized in the first section in tabular form. The second section is devoted to monochrome standards. It contains some elementary tutorial material intended for the reader who is not directly involved with television. The third section is devoted to the NTSC color standard--its description, its history, and its successors overseas.

More than almost any other signal, the television signal is a highly artificial thing. It is interesting therefore to discover that most systems in use around the world are very similar. Some explanation of why this should be is offered in the subsequent sections covering the properties of vision and of the monochrome and color standards.

Not treated in this annex are advances in picture representation and current practices in closed-circuit television applications.

I-1 SOME USEFUL PSYCHOPHYSICAL PROPERTIES OF VISION

Human vision and its characteristics have played an integral part in signal specifications of television systems where its deficiencies are put to good use. Hence, the eye is the logical starting place if one wishes to understand existing specifications and assess their adequacy. While much can be learned from the physiological structure of the eye and the visually related nerve and brain elements, much of the subject is psychological in nature, in that it relates to sensation, hence the term psychophysics (the relations between mental phenomena and physical changes). A recent extensive review of the subject has been given by Wilder (1973). An older source is Fink (1957) which is still pertinent (and probably more accessible reference). The ranges of some critical psychophysical parameters are given in Table I.

Colorimetry, the study of color, is an exceedingly important aspect of color television, and is reviewed in Nimeroff (1968). Applications of colorimetry to the formulation of the NTSC Color Television Standards may be found in Wintringham (1951) and in Fink (1957).

Several characteristics of the eye can be exploited in formulating television color specifications. Firstly, visual acuity is less for color than for black and white. In fact, if the detail is given in black and white the eye is practically insensitive to color changes in small areas. In addition, perception of color difference is less for blue than for green as is illustrated through MacAdam (1942); perceptibility ellipses in Fink (1957). Hence, if fine detail is shown in black and white, medium detail in two colors, and large areas, only, in full three color reproduction, the eye is none the wiser. In addition, the detail (bandwidth) required for blue is significantly less than that for red and green.

The Television Allocations Study Organization (TASO) also undertook in its Panel 6 in 1958 a study of the subjective effects of interference and noise on picutre quality. Reports on this work may be found in Dean (1960) and Fredenhall and Behrend (1960). More recent studies are reviewed in Wilder (1973) and in the documentation of CCIR Study Group 11.

(Annex I). Table I. Psychophysical Properties of the Eye Pertinent to Television.

Psychophysical Property	Description	Physical Conditions Affecting Value	Values Appropriate to Room Condition		Comments	References
			Best Single Value	Range		
1. Visual Acuity	ability of the eye to resolve or distinguish closely adjacent objects	1) increase with illumination to a point then decreases	1 minute of arc	0.4 to 5 minutes of arc	20/20 vision means a person can resolve 1 minute of arc at 20 feet, 20/40 vision to 2 minutes of arc	Wilder (1973) Bartley (1958) Hecht & Mintz (1939)
2. Flicker fusion frequency (or critical frequency)	with increasing frequency, the value at which pulses of light appear steady to the eye	1) increases with pulse intensity 2) increases with stimulus size 3) varies with part of spectrum 4) varies with area of retina covered	30 flashes per second	10 to 60 Hz	below a certain luminance the fusion frequency becomes very much a function of color. For a given illumination in this range the fusion frequency is higher for blue than red	Fink (1957) Bartley (1958)
3. Contrast Sensitivity	the ability of the eye to just distinguish an object of brightness B+ΔB compared to a background of brightness B	1) Weber's law states ΔB = KB where: B is intensity and K is an observer constant 2) Weber's law holds fairly well for cone vision (bright) but breaks down for rod (dim) vision 3) Size of area is factor	1% change ($K \simeq 1.01$)	0.5% to 10% change ($0.005 < K < 0.1$)	illumination units are confusing. Consult someone knowledgeable if possible	Wilder (1973) Fink (1957) Gregory (1956)
4. Color Perception	the ability of the eye to distinguish differences in hue	1) hue unresolvable for fine detail 2) color preception is highest in blue-violet, least in green			color TV uses one color signal for fine detail, two for medium detail and three for gross detail	Wintringham (1951) Nimeroff (1968) Fink (1957)
5. Eye motions of the awake human	1) nystagmus motions are of low amplitude and high frequency and are involuntary 2) Saccadic motions are involved when examining a target 3) drift motions when fixating a target				eye motions are important even in viewing stationary targets as they translate spatial gradients into temporal gradients for which the cones are known to response	Kolers (1968) Higgins & Stultz (1953) Wilder (1973)

I-2 MONOCHROME TELEVISION TRANSMISSION STANDARDS

NTSC Television Standards stand as an accomplishment in government-industry collaboration for which the U.S. may be rightfully proud. The monochrome (black and white) standards were formulated in 1939 by the National Television Systems Committee and are still in effect in the U.S. In November 1950, the NTSC was reformed to coordinate the development work on a simultaneous color-television system (Townsend, 1970. Their efforts were made public in 1953 (see Section 8, IRE, 1954) and are described in Section 6.9.3.

Good descriptions of the monochrome and color standards may be found in Section 73.682 of the FCC Rules and Regulations, in Fink (1957), in Martin (1962), in Bell (1964, Chapter 16), ITT (1972, Chapter 28) and many others. All the material given below may be found in the above four references.

Having formulated these standards, the principal activity (and appropriately so) in the U.S. has been to develop the broadcasting industry inside the confines of the present standards, rather than to work on the next generation standards.

I-2.1 NTSC Standard

The NTSC transmission monochrome standards may be itemized as follows:

Channel width: 6 MHz.

Picture carrier location: 1.25 MHz ± 1000 Hz above visual carrier.

Aural center frequency: 4.5 MHz ± 1000 Hz above visual carrier.

Polarization of radiation: Horizontal.

Modulation: Amplitude-modulated (vestigial lower sideband) composite picture and synchronizing signal on visual carrier, together with frequency modulated audio signal on the aural carrier.

Scanning lines: 525 lines per frame interlaced two to one in successive frames.

Vertical scanning frequency: 60 Hz.

Aspect ratio: 4 units horizontally to 3 units vertically.

Blanking level: Shall be transmitted at 75 ± 2.5 percent of the peak carrier level.

Reference black level: Separated from the blanking level by 7.5 ± 2.5 percent of the video range from blanking level to reference white level.

Reference white level: 12.5 ± 2.5 percent of peak carrier.

Polarity of transmission: Negative--a decrease in initial light intensity causes an increase in radiated power.

Transmitter brightness response: Radio-frequency output varies in an inverse logarithmic relation to the brightness of the scene.

Aural-transmitter power: Maximum radiated power is 20% and the minimum 10% of peak visual transmitter power (7 to 10 db down).

I-2.2 The Concept

The general scheme of television transmission is portrayed in Figure An-1(a). The television signal needs to convey information for two space dimensions and one of time. Coverage of the space dimensions is achieved by scanning the scene to be transmitted with an electron beam in a systematic fashion and requiring that at the receiver scanning

take place which is synchronized to that at the studio. It is then only necessary to convey brightness (luminance) information in order to reproduce the scene in the studio.

How the scene is scanned is totally arbitrary. One could start from the center and spiral outwards. The NTSC choice was to start at the upper left-hand corner of the picture, and scan horizontally (almost) across the picture (A to B in Fig. An-1(b)). The beam then blacks out while it retraces to the left side (C in Fig. An-1(b)). Taking 1 minute of arc for the resolving power of the eye (see Table I) and 6 times the height of the picture as the minimum viewing distance, just over 500 lines are required if the lines are not to be distinguished, hence the choice of 525 lines. Commercial motion picture practice is 24 frames a second but actually 48 pictures per second are projected on the screen (each picture being shown twice) so the effective flicker rate is 48 per second. However, it was felt that there were to be advantages in using a submultiple of the power source so 30 cycles was chosen for the frame rate. The flicker rate was reduced by specifying that the odd lines be scanned first, subsequently the even lines. The pattern of scanning lines constitutes what is known as the raster, and the technique is called interlace scanning. The horizontal motion of the scanning beam in the receiver is accomplished by impressing a saw-tooth wave form with period 63.5 microseconds (15,750 Hz) on the horizontal deflection plates of the kinescope (see Fig. An-1(c)), and the vertical motion by impressing one of period 16,666 microseconds (60 Hz) on the vertical plates (Fig. An-1(d)). It is necessary to complete each vertical sweep cycle exactly one-half horizontal line different from the previous scan if the interlace is to come out spaced uniformly (see Fig. An-1(e)). It was then recognized that the vertical and horizontal saw tooth deflection

signals should originate from the same 15,750 Hz oscillator. The picture (or frame) frequency (30 Hz) is obtained by dividing successively by 3, 5, 5, and 7 (whose product equals 525).

I-2.3 Synchronization

The synchronization pulses which keep the camera scan at the TV station synchronized with the scan on the receiver picture-tube are of three types: horizontal synchronization pulses, vertical synchronization pulses, and equalization pulses. The horizontal synchronization pulses are found during the line retrace period when the beam is dark and also during the field retrace period along with the vertical synchronization pulses and equalization pulses.

Horizontal or "line" synchronizing pulses are shown in Figure An-2. Of the 63.5 microsecond period (H) between the start of one line and the start of the next, 10.3 microseconds is taken up by a blanking pulse which, in the positive modulation form shown in Figure An-2, drops the signal level below the black level. (The transmitted waveform has negative modulation and resembles Figure An-2. The horizontal synchronizing pulse follows the blanking pulse by 1.3 microseconds and drops the signal still farther. It lasts 4.5 microseconds.

The vertical synchronization situation is complicated by the non-integer number of lines per field. The vertical blanking interval used to be defined (Fink, 1957, p. 2-4) in terms of a maximum period of 21 lines (1333.5 microseconds) to a minimum of 13.1 lines (831.85 microseconds). Paragraphs 21 and 22 of 73.682 of the FCC rules imply that there are to be at least 23 lines during vertical blanking. This implies that there are only 525-2(23) = 479 active lines/frame. The vertical retrace period is portrayed in Figure An-3. The vertical synchronization pulse has a width of 190.5 microseconds (3 H), 42 times the width of the horizontal synchronization pulses (which still appear throughout

the vertical blanking period). The leading edge of the vertical synchronization pulse is shifted one half H relative to the horizontal synchronization pulses on successive fields. This could throw the picture out of synchronization. The equalizing pulses are put in to correct this situation by "swamping". They look like horizontal synchronization pulses and are placed midway between the line synchronization pulses for 190 microseconds (3 H) on either side of the vertical synchronization pulse.

I-2.4 Amplitude Levels (D. C. Component)

The complete video signal has four distinct amplitude levels associated with it: the white level, the black level, the blanking level, and the level of the tips of the synchronizing pulses.

Paragraph 73.682 of the FCC Rules and Regulations specifies these levels for the transmitted video signal (negative polarity) as follows:

White level: 12.5 ± 2.5% of the peak carrier level.

Black level: A definite carrier level, independent of light and shade in the picture. The black level shall be separated from the blanking level by the setup interval which shall be 7.5 ± 2.5% of the video range from the blanking level to the reference white level.

Blanking level: 75 ± 2.5% of the peak carrier level.

Synchronization pulse (synchronization tips): Maximum voltage for the picture carrier.

It is further specified that the transmitter output "shall vary in substantially inverse logarithmic relation to the brightness of the subject". (This last requirement is to balance the exponential brightness to voltage characteristic of picture tubes in the receiver.) The various relative levels for the two different polarities are summarized below.

	Relative Voltage Level	
	Negative Pol.	Postiive Pol.
Synychronization tips	1.0	0.0
Blanking level	.75	.286
Black level	.703	.34
White level	.125	1.0

The various shades of grey in a picture element are contained in the d-c level of the signal at the picture tube. This is sometimes a problem in receivers using capacitors for coupling. Where d-c coupling is not possible, d-c restoration can be accomplished through clamping circuits in the receiver.

I-2.5 Video Spectrum

The transmitted spectrum is essentially that of Figure An-5(a) where the overall envelope is governed largely by the various step functions in the waveform. The gross line structure is made up of the harmonies of the line scanning frequency (15,750 MHz) of which there are 253 in 4 MHz. Closer examination of each one of these "lines" discloses that it is made up of a fine structure of lines at the frame repetition frequency (30 Hz). The lines which also correspond to harmonics of the field repetition frequency (60 Hz) have greater amplitude, thus the apparent two sets of lines around each field repetition harmonic. If frame-to-frame picture motion exists, then a broadening of the lines will take place such as shown in Figure An-5(b), and the relative amplitudes of the lines will also change. Another example is shown in Figure An-6.

Perhaps, the two most important features to note are first, that most of the energy is under 100 kHz, and secondly, that the spectrum is a line spectrum made up of lines whose frequencies are invariant. Ingenious use is made of this last feature when color is added.

I-2.6 Sound

The aural part of the composite TV signal is braodcast with an entirely separate transmitter. The sound carrier is placed 4.5 MHz above the picture carrier, just outside the picture sideband. Frequency modulation is employed with a maximum frequency excursion of 25 kHz and a pre-emphasis of 75 microseconds. The pre-emphasis curve is such that the aural signal is boosted 1 db at 1 kHz, 14 db at 10 kHz and 17 db at 15,000 kHz.

I-2.7 Test Signals

The FCC regulations specify that lines 17 through 20 of each vertical blanking interval of each field can be used for test signals (¶ 73.682, item 21), and lines 21 through 23 may contain "coded patterns for the purpose of electronic identification...and spot announcements." This means that $4 \times 60 \times 63.5 = 15,250$ microseconds are available for special signalling, such as is currently being developed by NBS.

I-2.8 Complete Television Channel

The idealized transmitted signal as given in the FCC Rules for channels 2-13 is shown in Chapter 9. (The chrominance sub-carrier is included for future reference.) The video information is contained in the upper sideband, but it was not considered technically feasible to completely suppress the lower sideband. The result is a vestigial lower sideband which resulted from a compromise between bandwidth economy and ease of design. The upper sideband is progressively

attenuated beyond 4.2 MHz from the video carrier, becoming negligible at the sound carrier. Similarly, the vestigial lower sideband is attenuated beyond 0.75 MHz becoming negligible below 1.25 MHz.

I-3 THE NTSC COLOR TELEVISION STANDARDS

I-3.1 Summary

The basic elements of the NTSC color TV standards can be summarized as follows.

(a) The modulation signal consists of:

1) a 3.579545 MHz (referred to as 3.58 MHz signal) color synchronization burst of a minimum of 8 cycles, occurring on the back porch of the sync signal during horizontal blanking;

2) the full 4.5 MHz luminance signal E_Y' where $E_Y' = 0.30\, E_R' + 0.59\, E_G' + 0.11\, E_B'$;

3) the chrominance signal, E_I', transmitted vestigial sideband on a suppressed carrier of 3.58 MHz; the full lower sideband of 1.5 MHz is retained, while the upper sideband is truncated at 0.5 MHz, where $E_I' = -0.27\,(E_B' - E_Y') + 0.74\,(E_R' - E_Y')$;

4) the chrominance signal, E_Q', transmitted with both 0.5 MHz sidebands on the same suppressed subcarrier of 3.58 MHz as the E_Q' signal but orthogonal to it, where $E_Q' = 0.41\,(E_B' - E_Y') + 0.48\,(E_R' - E_Y')$.

(b) The color reproduction is accomplished by:

1) creating three separate gamma-corrected color signals at the origination studio corresponding to three primary colors: red, green, and blue (E_R', E_G', E_B');

2) mixing these three color signals in a passive matrix to produce the luminance signal, E_Y' (considered identical to the monochrome signal). (The luminance signal E_Y' can be received on a black-and-white receiver.);

3) mixing the three color signals again in two matrices to produce the E_I' and E_Q' signals. The I axis (maximum eye sensitivity) on the color diagram corresponds to orange-cyan (a blue-green) and receives the maximum bandwidth (1.5 MHz). The Q axis (lower eye sensitivity) corresponds to violet-yellow-green and receives the minimum bandwidth (0.5 MHz). The signals are transmitted in quadrature. E_I' leads $E_{(R'-Y')}$ by 33° and E_Q' leads $E_{B'-Y'}$ by 33°.

4) At the receiver the luminance signal E_Y' is detected in the usual way. Synchronous demodulators (locked to the transmitted color burst) derive the E_I' and E_Q' signals. These are then matrixed with the E_Y' signal to produce three color signals

$$E_R' = E_Y' + 0.62\ E_Q' + 0.96\ E_I' \ ,$$

$$E_G' = E_Y' + 0.64\ E_Q' - 0.281\ E_I' \ ,$$

$$E_B' = E_Y' + 1.72\ E_Q' - 1.11\ E_I'.$$

These three color signals (red, green, and blue) are then applied to the tri-color picture tube to reproduce the original scene.

I-3.2 The NTSC Color TV Standards Work

As mentioned earlier, the National Television System Committee was reactivated in November 1950 under the aegis of the RTMA. Also in November of 1950, the FCC amended its "Standards of Good Engineering Practice Concerning Television Broadcast Stations" to incorporate a section on color transmission (Goldmark, et al., 1951).

It defined a field-sequential system, interlaced two-to-one in successive fields of the same color. The number of lines per frame was 405. The frame frequency was set at 72; the field frequency, 144; the color frame frequency, 24; the color field frequency, 48; and the line frequency, 29160 per second. The system was incompatible with the monochrome standards (i.e., the normal black and white receiver could not be used to watch a color transmission in monochrome).

In April of 1951, the Ad Hoc Committee on color television made a significant series of recommendations (NTSC-AHCT-75) concerning the form of the color system (Baker, 1954). "The luminance, or "brightness," component of the color picture should be transmitted according to the present monochrome standards, so that it might be received as a monochrome "base" picture of quality comparable to present monochrome pictures. The additional "coloring" information should be transmitted simultaneously in the form of two independent signals modulating a single subcarrier which is located in the video band of the monochrome signal. The subcarrier frequency should be so located with respect to the video carrier that any interference it produces with the monochrome signal will have a minimum visibility. A color synchronizing signal, required by the receiver for proper detection of the color subcarrier, should be added to the present sync signals during an interval available under present standards."

These recommendations set the stage for the work of the NTSC Panels and their sub-committees concerned with color television (Panels 11 through 19). Two results were sought through analysis--experiment and field tests (Baker, 1954):

1. To achieve the highest possible quality of color service through the choice of signals which, by matching the

characteristics of color vision, allow the transmission of a visually high quality color picture with a maximum economy of bandwidth, and

2. To insure a continuing monochrome service of quality equal to the present one by transmitting the additional color signals in such a manner that they do not interfere with proper operation of unmodified monochrome receivers.

The NTSC followed the organizational pattern which had proved successful for the first NTSC: specifically, to name a distinguished individual to direct the work of each panel, to then open the membership to all interested participants, and finally, to pay careful attention to inter-panel liaison. Notable success was again achieved through this pattern. After two years, their findings were made public in a special issue on color television devoted to the work of the NTSC and containing 53 papers amounting to over 300,000 words (see Section 8, IRE, 1954). Although good integration of the material may be found in Fink (1957), these papers still stand as the basic resource material on the NTSC standards.

The recommendations of the NTSC were submitted to the FCC in the form of a petition on July 23, 1953 and were approved on December 17, 1953.

One of the most illuminating comments on the work of the second NTSC was given recently by Townsend (1970) in a book co-sponsored by the Institution of Electrical Engineers (London). The following paragraph is reproduced from Section 1.8:

"The organization of the NTSC was broad in vision, large in scale, and remarkably effective. By the end of 1953, the fruits of hundreds of thousands of voluntarily contributed engineering man hours were finally seen by the public,

when a new form of broadcasting began. An all electronic simultaneous colour system using a compatible monochrome signal interleaved with a low visibility colour subcarrier, tailored to the requirements of human vision and to the existing black-and-white television network, had been developed. It had been exhaustively analysed, the work of all of the NTSC panels had been published for criticism, extensive field tests had been undertaken, and government approval had been obtained: It provides an object lesson in the management of technological development."

I-3.3 Color Television Broadcasting in other Countries

A review of the actual signal specifications adopted by other countries of the world are in CCIR Reports 407-1(Rev72) on color and 308-2(Rev72), CCIR (1970) on monochrome TV. Both Reports are found in Part I of the conclusions of the 1972 Interim Meetings of Study Group 11, CCIR, ITU, Geneva.

There are two additional color systems operating in Europe, both of which were developed subsequent to the NTSC. Secam, derived from "séquentiàl couleur a memoire" is an outgrowth of suggestions made in 1959 by Henre de France. In Secam a luminance signal on its carrier and two color-difference signals on an FM subcarrier are transmitted, alternately. The two color signals at the receiver then modulate lines in alternating sequence. The Secam system involves a line interval store in the receiver (Townsend, 1970). It was adopted by France and the Soviet Flock in the mid-sixties.

The Pal system, an acronym for NTSC plus "phase-alternation line" was developed by W. Bruch of West Germany following a suggestion made by Loughlin in 1951 for "oscillating-colour sequence", plus the line-store scheme of Secam. Germany and the UK began their public services on the Pal system in 1967.

Both the EBU (European Broadcasting Union) and the CCIR (International Radio Consultative Committee) attempted comparison of the three systems in the 1963 to 1966 period, and both groups ended shedding more heat than light on the subject. It is probably safe to conclude that Secam and Pal are only incrementally different from NTSC and do not represent a new generation.

It is also clear that a proposal to change broadcasting TV standards should not be made lightly of in view of the difficulty in repeating the "hundreds of thousands of man-hours" which went into the second NTSC, not to mention the $20 billion investment in television sets in the hands of the public (roughly 10^8 sets at $200/set).

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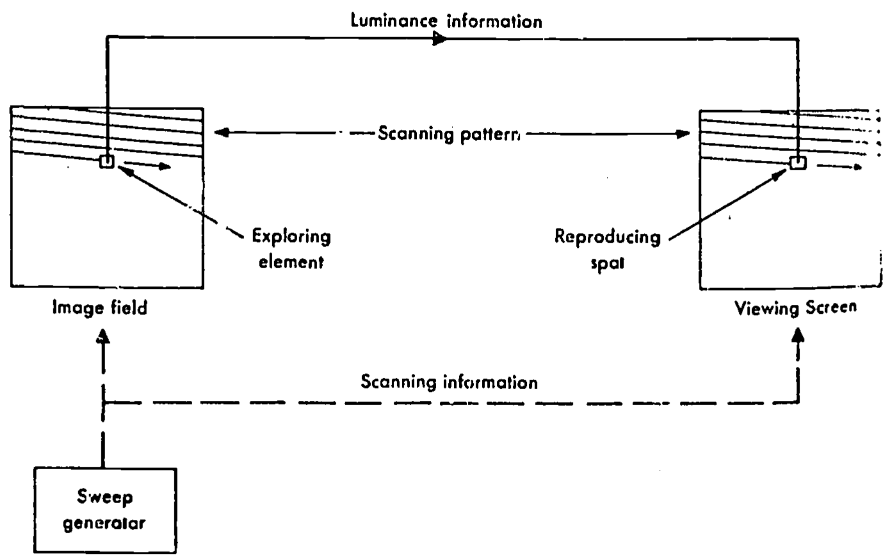
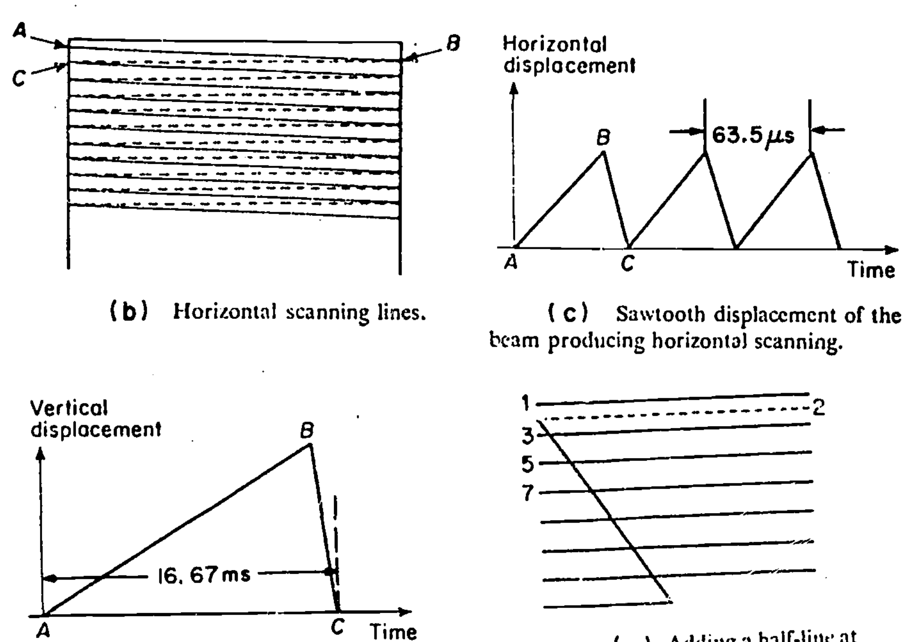


(a) General scheme of television transmission.

[Reprinted by permission from Bell Telephone Laboratories, Inc., Copyright 1964.]



(b) Horizontal scanning lines.

(c) Sawtooth displacement of the beam producing horizontal scanning.

(d) Vertical scanning is the result of a sawtooth motion.

(e) Adding a half-line at the end of the picture produces interlace.

Figure An-1. Features of the NTSC Monochrome Television System (b) through (e) (Martin, 1962). [Reprinted by permission from Prentice-Hall, Inc., Copyright 1962.]

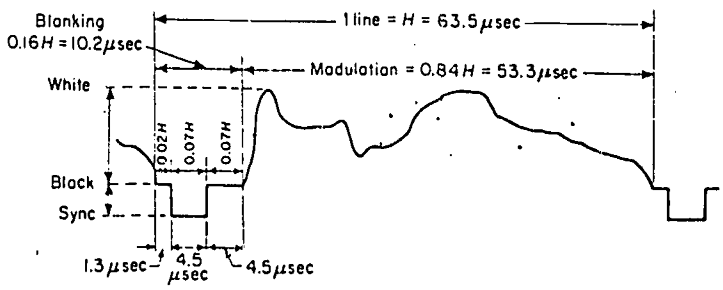


Figure An-2. Standard Durations for a Line Period (Martin, 1962). [Reprinted by permission from Prentice-Hall, Copyright 1962.]

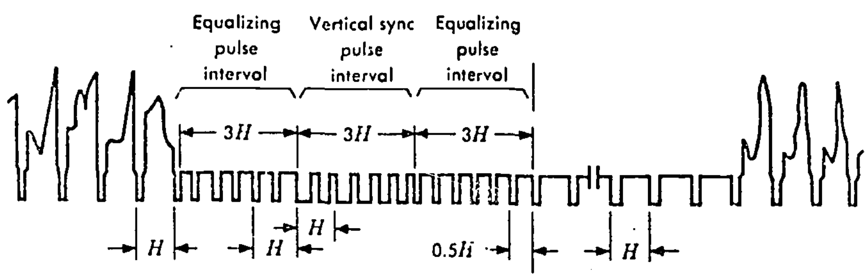


Figure An-3. Portion of Television Signal Showing Field, Synchronization Pulses. [Reprinted by permission from Bell Telephone Laboratories, Copyright 1964.]

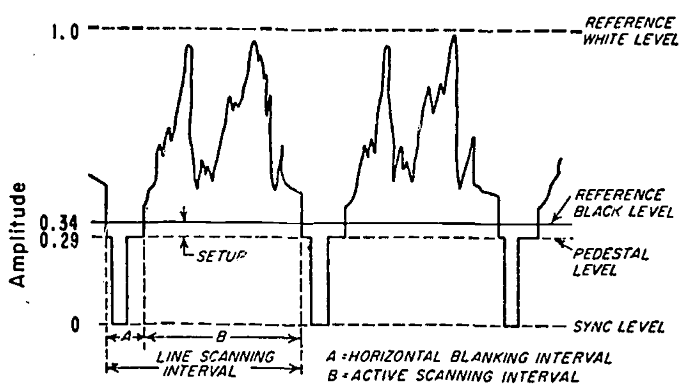
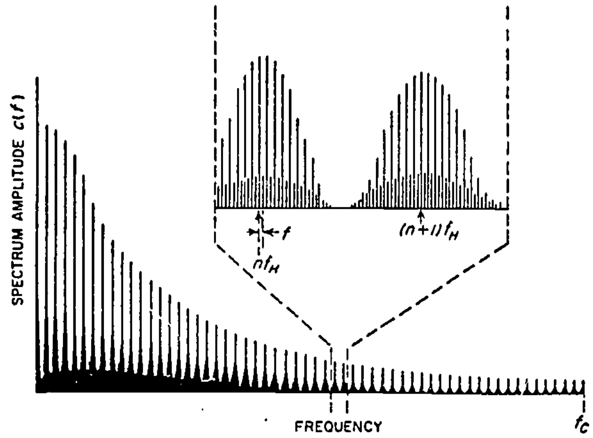
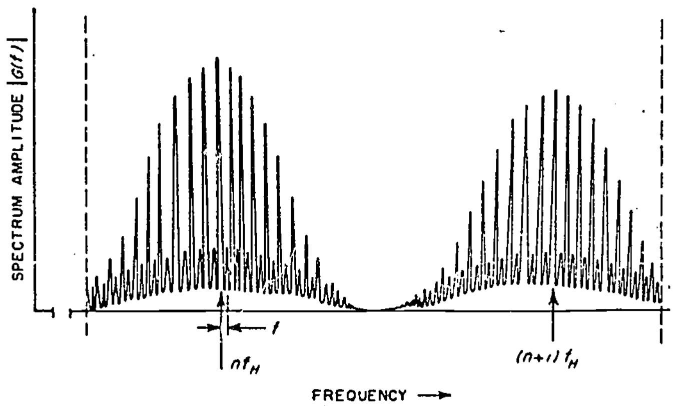


Figure An-4. Monochrome Signal Waveform Showing Relative Amplitude Levels.



a) Video Signal Associated with a Stationary Picture.



b) Video Signal Associated with a Picture Containing Motion.

Figure An-5. Fine Structure of the Video Spectrum the f, f_H, and f_c are Frame Scanning, Line Scanning, and Video Cutoff Frequencies Respectively (Fink, 1957).

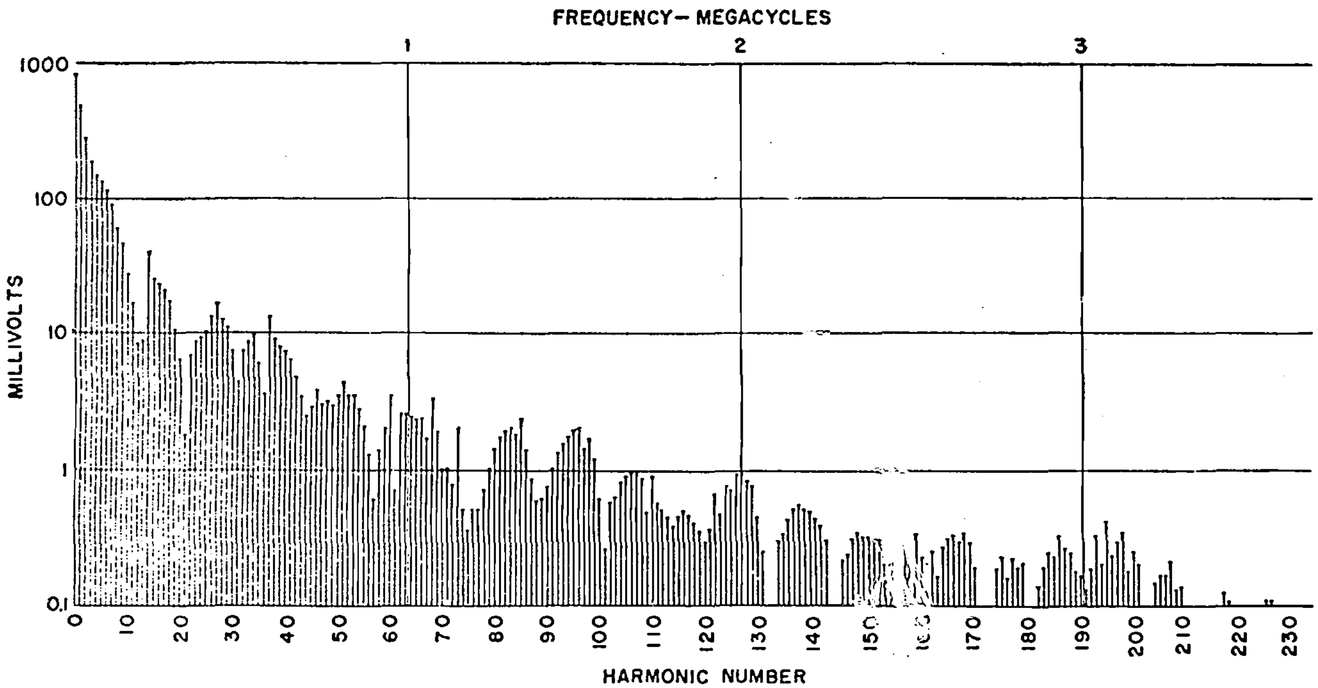


Figure An-6. Measured Spectrum of Gray-scale Signal (Fink, 1957).
[Reprinted by permission from McGraw Hill, Copyright.]

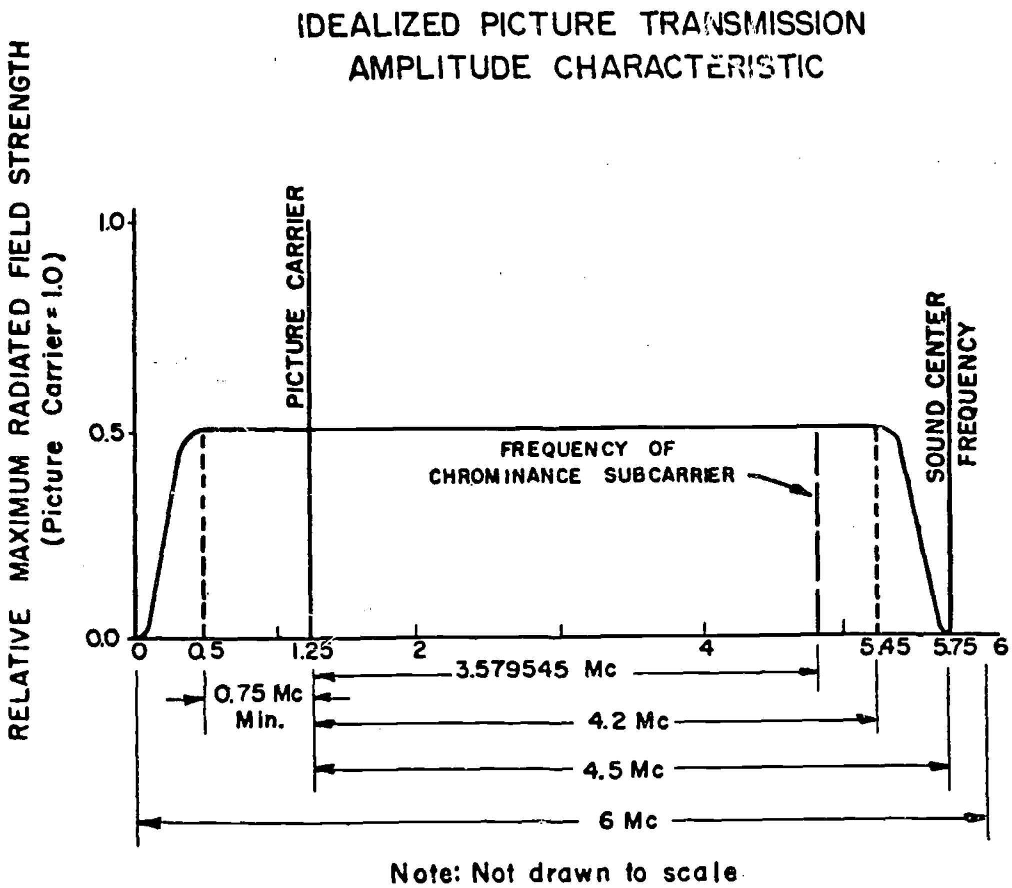


Figure An-7(a). Idealized picture transmission amplitude characteristic (Fig. 5 of FCC ¶ 73.699).

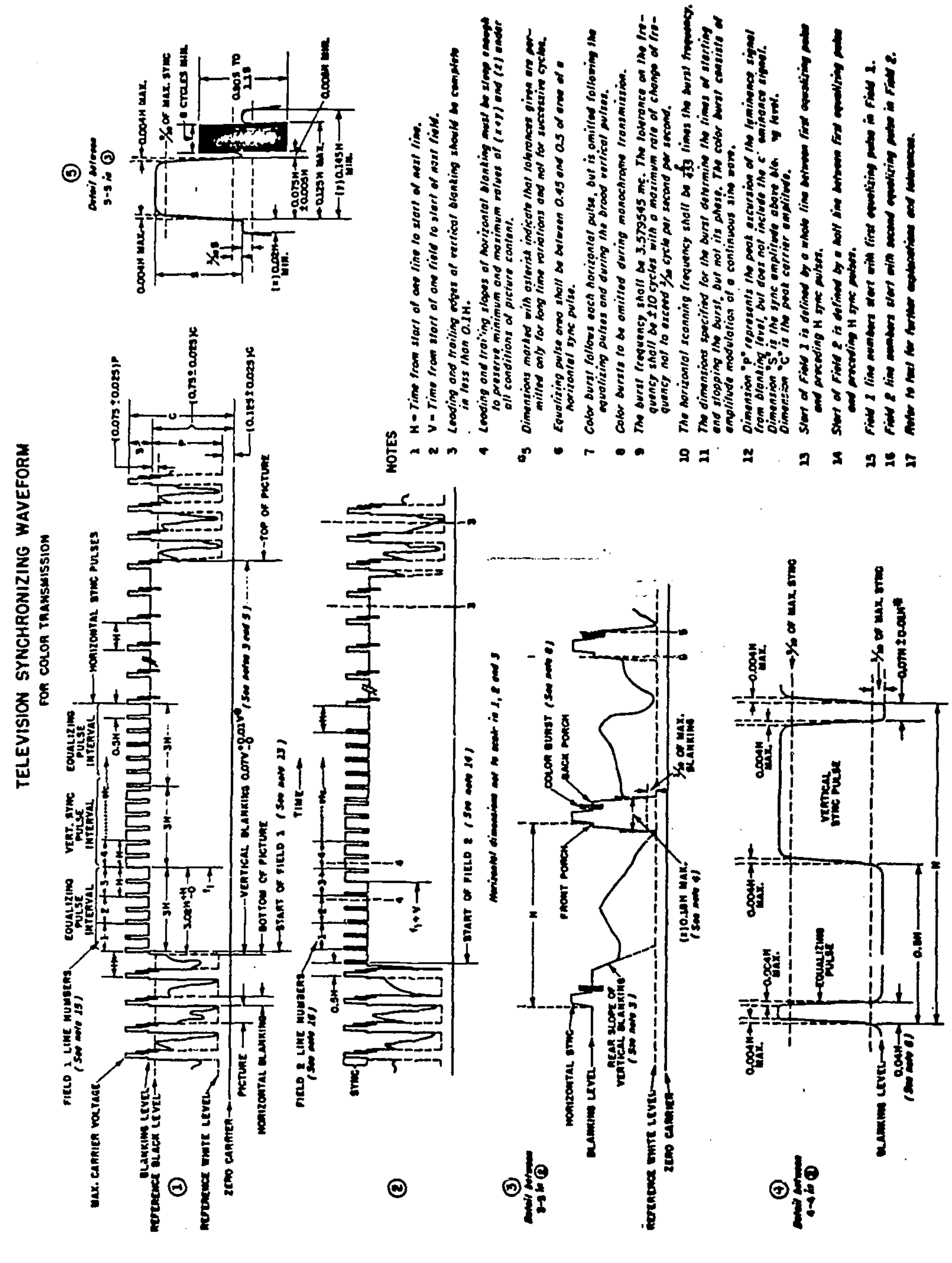


Figure An-7(b). Television synchronizing waveform for color transmission (Fig. 6 of FCC ¶ 73.699).

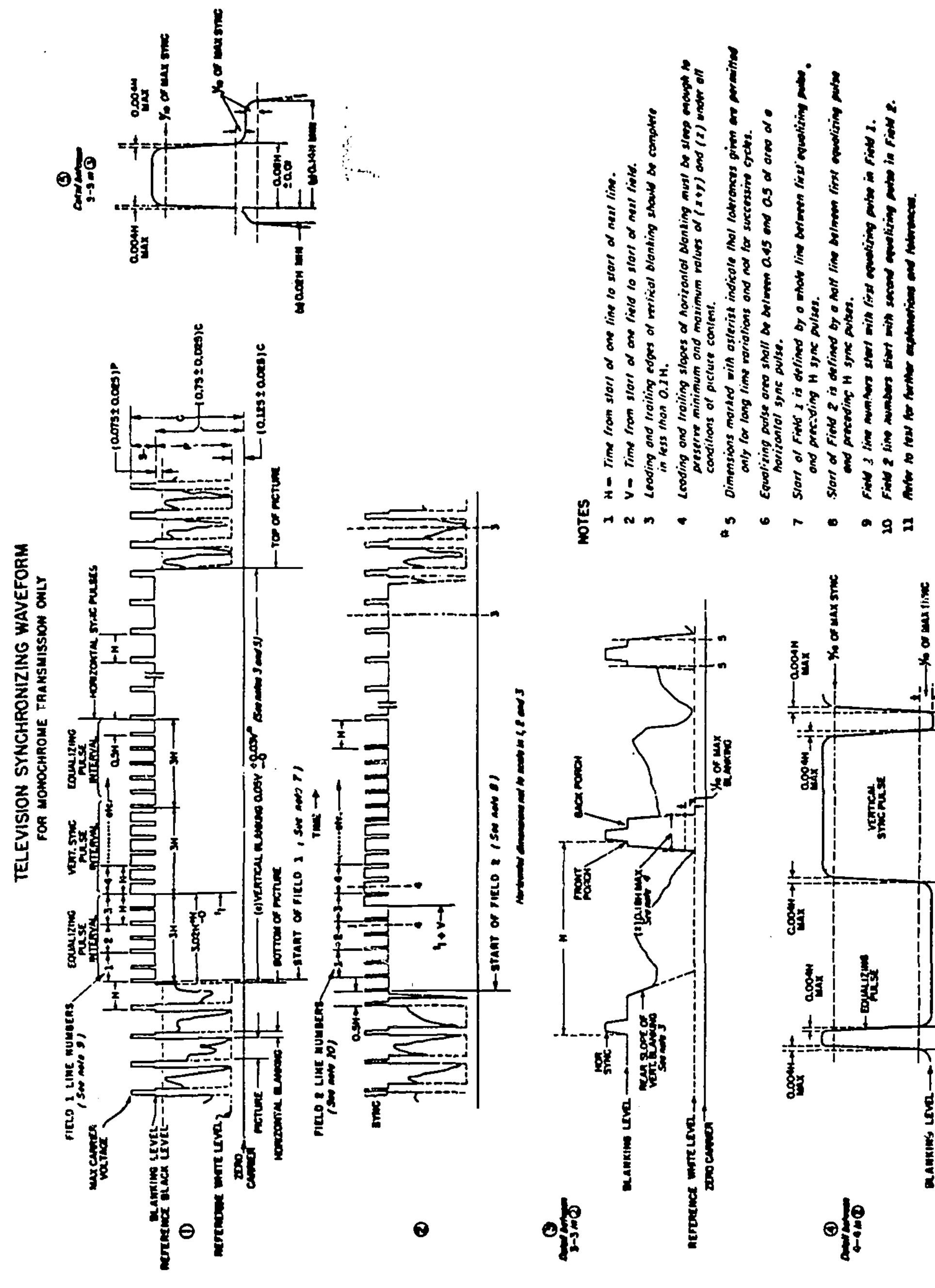


Figure An-7(c). Television transmission waveform for monochrome transmission only (Fig. 7 of FCC ¶ 73.699).

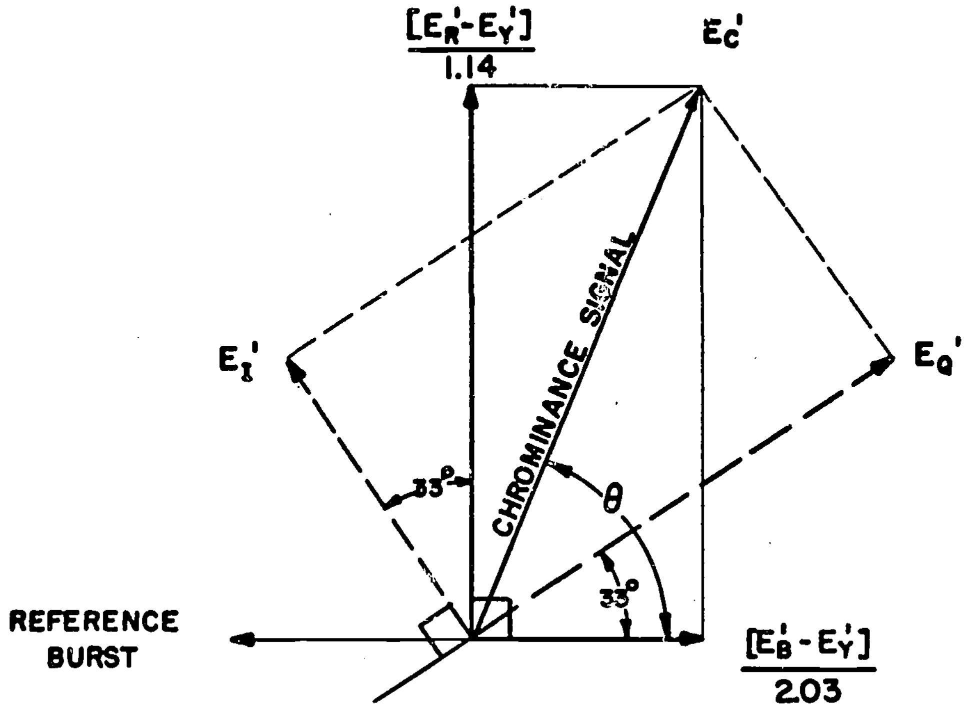


Figure An-7(d). Phase relationships of the chrominance signal and the reference color burst (Fig. 8 of FCC ¶ 73.699).

ANNEX II SELECTED STRANDARDS

CONTENTS

ANNEX II

II SELECTED STANDARDS

Included in this Annex are CATV related technical standards, some of which are reproduced in their entirety, and others by outline. The FCC Cable Standards are given in full as are the CCIR Recommendation and the two CCIR Reports: Recommendation 470(Rev72), Television Systems; Report 308-2(Rev72), Characteristics of Monochrome Television Systems; and Report 407-1(Rev72), Characteristics of Colour Television Systems. The authors would like to thank Mr. Jack W. Herbstreit, Director of the CCIR, for the reports and to repeat his admonition that the 1972 revisions (Rev72) of these reports will not become official in the CCIR until after their 1974 Plenary Meeting.

The IRE, NCTA, and EIA standards are excerpted from an unpublished report by Dr. Mark T. Ma of the Office of Telecommunications.

SELECTED STANDARDS

II. I FCC CABLE STANDARDS--SUBPART K

The material in this section is taken from the Federal Register, Vol. 37, No. 30, Saturday, Feb. 12, 1972, pp. 3290-3292.

Subpart K—Technical Standards

§ 76.601 Performance tests.

(a) The operator of each cable television system shall be responsible for insuring that each such system is designed, installed, and operated in a manner that fully complies with the provisions of this subpart. Each system operator shall be prepared to show, on request by an authorized representative of the Commission, that the system does, in fact, comply with the rules.

(b) The operator of each cable television system shall maintain at its local office a current listing of the cable television channels which that system delivers to its subscribers and the station or stations whose signals are delivered on each Class I cable television channel, and shall specify for each subscriber the minimum visual signal level it maintains on each Class I cable television channel under normal operating conditions.

(c) The operator of each cable television system shall conduct complete performance tests of that system at least once each calendar year (at intervals not to exceed 14 months) and shall maintain the resulting test data on file at the system's local office for at least five (5) years. It shall be made available for inspection by the Commission on request. The performance tests shall be directed at determining the extent to which the system complies with all the technical standards set forth in § 76.605. The tests shall be made on each Class I cable television channel specified pursuant to paragraph (b) of this section, and shall include measurements made at no less than three widely separated points in the system, at least one of which is representative of terminals most distant from the system input in terms of cable distance. The measurements may be taken at convenient monitoring points in the cable network: *Provided*, That data shall be included to relate the measured performance to the system performance as would be viewed from a nearby subscriber terminal. A description of intruments and procedure and a statement of the qualifications of the person performing the tests shall be included.

(d) Successful completion of the performance tests required by paragraph (c) of this section does not relieve the system of the obligation to comply with all pertinent technical standards at all subscriber terminals. Additional tests, repeat tests, or tests involving specified subscriber terminals may be required by the Commission in order to secure compliance with the technical standards.

(e) All of the provisions of this section shall become effective March 31, 1972.

§ 76.605 Technical standards.

(a) The following requirements apply to the performance of a cable television system as measured at any subscriber terminal with a matched termination, and to each of the Class I cable television channels in the system:

(1) The frequency boundaries of cable television channels delivered to subscriber terminals shall conform to those set forth in § 73.603(a) of this chapter: *Provided, however*, That on special application including an adequate showing of public interest, other channel arrangements may be approved.

(2) The frequency of the visual carrier shall be maintained 1.25 MHz$\pm$25 kHz above the lower boundary of the cable television channel, except that, in those systems that supply subscribers with a converter in order to facilitate delivery of cable television channels, the frequency of the visual carrier at the output of each such converter shall be maintained 1.25 MHz$\pm$250 kHz above the lower frequency boundary of the cable television channel.

(3) The frequency of the aural carrier shall be 4.5 MHz$\pm$1 kHz above the frequency of the visual carrier.

(4) The visual signal level, across a terminating impedance which correctly matches the internal impedance of the cable system as viewed from the subscriber terminals, shall be not less than the following appropriate value:

Internal impedance:
75 ohms.
300 ohms.
Visual signal level:
1 millivolt.
2 millivolts.

(At other impedance values, the minimum visual signal level shall be $\sqrt{0.0133\,Z}$ millivolts, where Z is the appropriate impedance value.)

(5) The visual signal level on each channel shall not vary more than 12 decibels overall, and shall be maintained within

(i) 3 decibels of the visual signal level of any visual carrier within 6 MHz nominal frequency separation, and

(ii) 12 decibels of the visual signal level on any other channel, and

(iii) A maximum level such that signal degradation due to overload in the subscriber's receiver does not occur.

(6) The rms voltage of the aural signal shall be maintained between 13 and 17 decibels below the associated visual signal level.

(7) The peak-to-peak variation in visual signal level caused undesired low frequency disturbances (hum or repetitive transients) generated within the system, or by inadequate low frequency response, shall not exceed 5 percent of the visual signal level.

(8) The channel frequency response shall be within a range of ±2 decibels for all frequencies within −1 MHz and +4 MHz of the visual carrier frequency.

(9) The ratio of visual signal level to system noise, and of visual signal level to any undesired cochannel television signal operating on proper offset assignment, shall be not less than 36 decibels. This requirement is applicable to:

(i) Each signal which is delivered by a cable television system to subscribers within the predicted Grade B contour for that signal, or

(ii) Each signal which is first picked up within its predicted Grade B contour.

(10) The ratio of visual signal level to the rms amplitude of any coherent disturbances such as intermodulation products or discrete-frequency interfering signals not operating on proper offset assignments shall not be less than 46 decibels.

(11) The terminal isolation provided each subscriber shall be not less than 18 decibels, but in any event, shall be sufficient to prevent reflections caused by open-circuited or short-circuited subscriber terminals from producing visible picture impairments at any other subscriber terminal.

(12) Radiation from a cable television system shall be limited as follows:

Frequencies	Radiation limit (microvolts/meter)	Distance (feet)
Up to and including 54 MHz	15	100
Over 54 up to and including 216 MHz.	20	10
Over 216 MHz	15	100

(b) Cable television systems distributing signals by using multiple cable techniques or specialized receiving devices, and which, because of their basic design, cannot comply with one or more of the technical standards set forth in paragraph (a) of this section, may be permitted to operate provided that an adequate showing is made which establishes that the public interest is benefited. In such instances the Commission may prescribe special technical requirements to ensure that subscribers to such systems are provided with a good quality of service.

(c) Paragraph (a)(12) of this section shall become effective March 31, 1972. All other provisions of this section shall become effective in accordance with the following schedule:

	Effective date
Cable television systems in operation prior to March 31, 1972	Mar. 31, 1977
Cable television systems commencing operations on or after March 31, 1972	Mar. 31, 1972

§ 76.609 Measurements.

(a) Measurements made to demonstrate conformity with the performance requirements set forth in §§ 76.701 and 76.605 shall be made under conditions which reflect system performance during normal operations, including the effect of any microwave relay operated in the Cable Television Relay (CAR) Service intervening between pickup antenna and the cable distribution network. Amplifiers shall be operated at normal gains, either by the insertion of appropriate signals or by manual adjustment. Special signals inserted in a cable television channel for measurement purposes should be operated at levels approximating those used for normal operation. Pilot tones, auxiliary or substitute signals, and nontelevision signals normally carried on the cable television system should be operated at normal levels to the extent possible. Some exemplary, but not mandatory, measurement procedures are set forth in this section.

(b) When it may be necessary to remove the television signal normally carried on a cable television channel in order to facilitate a performance measurement, it will be permissible to disconnect the antenna which serves the channel under measurement and to substitute therefor a matching resistance termination. Other antennas and inputs should remain connected and normal signal levels should be maintained on other channels.

(c) As may be necessary to ensure satisfactory service to a subscriber, the Commission may require additional tests to demonstrate system performance or may specify the use of different test procedures.

(d) The frequency response of a cable television channel may be determined by one of the following methods, as appropriate:

(1) By using a swept frequency or a manually variable signal generator at the sending end and a calibrated attenuator and frequency-selective voltmeter at the subscriber terminal; or

(2) By using a multiburst generator and modulator at the sending end and a demodulator and oscilloscope display at the subscriber terminal.

(e) System noise may be measured using a frequency-selective voltmeter (field strength meter) which has been suitably calibrated to indicate rms noise or average power level and which has a known bandwidth. With the system operating at normal level and with a properly matched resistive termination substituted for the antenna, noise power indications at the subscriber terminal are taken in successive increments of frequency equal to the bandwidth of the frequency-selective voltmeter, summing the power indications to obtain the total noise power present over a 4 MHz band centered within the cable television channel. If it is established that the noise level is constant within this bandwidth, a single measurement may be taken

which is corrected by an appropriate factor representing the ratio of 4 MHz to the noise bandwidth of the frequency-selective voltmeter. If an amplifier is inserted between the frequency-selective voltmeter and the subscriber terminal in order to facilitate this measurement, it should have a bandwidth of at least 4 MHz and appropriate corrections must be made to account for its gain and noise figure. Alternatively, measurements made in accordance with the NCTA standard on noise measurement (NCTA Standard 005-0669) may be employed.

(f) The amplitude of discrete frequency interfering signals within a cable television channel may be determined with either a spectrum analyzer or with a frequency-selective voltmeter (field strength meter), which instruments have been calibrated for adequate accuracy. If calibration accuracy is in doubt, measurements may be referenced to a calibrated signal generator, or a calibrated variable attenuator, substituted at the point of measurement. If an amplifier is used between the subscriber terminal and the measuring instrument, appropriate corrections must be made to account for its gain.

(g) The terminal isolation between any two terminals in the system may be measured by applying a signal of known amplitude to one and measuring the amplitude of that signal at the other terminal. The frequency of the signal should be close to the midfrequency of the channel being tested.

(h) Measurements to determine the field strength of radio frequency energy radiated by cable television systems shall be made in accordance with standard engineering procedures. Measurements made on frequencies above 25 MHz shall include the following:

(1) A field strength meter of adequate accuracy using a horizontal dipole antenna shall be employed.

(2) Field strength shall be expressed in terms of the rms value of synchronizing peak for each cable television channel for which radiation can be measured.

(3) The dipole antenna shall be placed 10 feet above the ground and positioned directly below the system components. Where such placement results in a separation of less than 10 feet between the center of the dipole antenna and the system components, the dipole shall be repositioned to provide a separation of 10 feet.

(4) The horizontal dipole antenna shall be rotated about a vertical axis and the maximum meter reading shall be used.

(5) Measurements shall be made where other conductors are 10 or more feet away from the measuring antenna.

§ 76.613 Interference from a cable television system.

In the event that the operation of a cable television system causes harmful interference to reception of authorized radio stations, the operation of the system shall immediately take whatever steps are necessary to remedy the interference.

§ 76.617 Responsibility for receiver-generated interference.

Interference generated by a radio or television receiver shall be the responsibility of the receiver operator in accordance with the provisions of Part 15, Subpart C, of this chapter: *Provided, however,* That the operator of a cable television system to which the receiver is connected shall be responsible for the suppression of receiver-generated interference that is distributed by the system when the interfering signals are introduced into the system at the receiver.

II-2 FCC TV Technical Standards

Section 73.681 Definitions

Section 73.632 Transmission Standards and Changes

Section 73.687 Transmitters and Associated Equipment

Section 73.689 Operating Power

Section 73.690 Frequency Measurements

Section 73.691 Modulation Monitors

Section 73.692 General Requirements for Type Approval of Frequency and Modulation Monitors

Section 73.694 Requirements for Type Approval of Aural Modulation Monitors

Fig. 9-1. Idealized picture transmission amplitude characteristic

Fig. 9-2. Idealized picture transmission amplitude characteristic

Fig. 9-3. Television synchronizing waveform for color transmission

Fig. 9-4. Television synchronizing waveform for monochrome transmission only

II-3 IRE Standards on Television, Proc. IRE, June 1960, pp 1125-1154.

Part I. Introduction

Chapter 1 - General

Chapter 2 - Requirements and characteristics of test apparatus

Part II. Picture Section of Receiver

Chapter 3 - Picture quality

Chapter 4 - Sensivity, picture

Chapter 5 - Interference, picture

Chapter 6 - Electrical fidelity, picture

Chapter 7 - Stability

Part III. Sound Section of the Receiver

Chapter 8 - Sensitivity

Chapter 9 - Interference, sound section

Chapter 10 - Fidelity, sound section

Chapter 11 - Radiated and conducted emissions

Chapter 12 - Miscellaneous

II-4 CCIR Technical Standards

The three CCIR documents which are reproduced here in full are updated versions of the official CCIR texts of the XIIth Plenary Assembly (1970) which bear the same document numbers. The documents reproduced here will become official if and when they are approved by the XIIIth Plenary Assembly of CCIR in 1974.

II-4.1 Recommendation 470(Rev72) Television Systems

SECTION 11A: CHARACTERISTICS OF SYSTEMS FOR MONOCHROME AND COLOUR TELEVISION

DRAFT RECOMMENDATION

DRAFT

RECOMMENDATION 470(Rev.'72)

TELEVISION SYSTEMS

The C.C.I.R., (1970-1974)

CONSIDERING

(a) that many countries have established satisfactory monochrome television broadcasting services based on either 525-line or 625-line systems;

(b) that a number of countries have established (or are in the process of establishing) satisfactory colour television broadcasting services based on the NTSC, PAL or SECAM systems;

(c) that it would add further complications to the interchange of programmes to have a greater multiplicity of systems;

RECOMMENDS

1. that, for a country wishing to initiate monochrome television service, a system using 525 or 625 lines as defined by the C.C.I.R. in Report 308-2 is to be preferred;
2. that, of the systems described in Report 308-2, systems *A*, *C*, *E* and *F* are not recommended for a new service;
3. that, for monochrome 625-line systems, the video-frequency characteristic described in Recommendation 472 is to be preferred;
4. that, for a country wishing to initiate a colour television service, one of the systems defined in Report 407-1 or any suitable adaption of the NTSC, PAL, or SECAM systems to any one of the monochrome systems defined in draft Report 308-2(Rev.'72) is to be preferred.

II-4.2 Report 308-2(Rev72) Characteristics of Monochrome Television Systems

DRAFT REPORTS

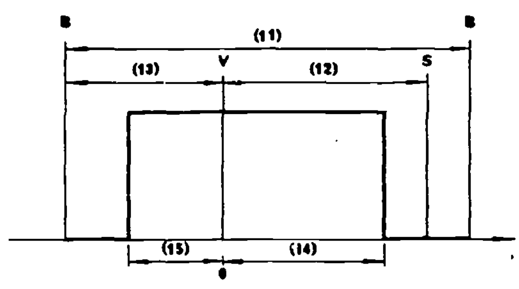
DRAFT

REPORT 308-2(Rev. '72)

CHARACTERISTICS OF MONOCHROME TELEVISION SYSTEMS

(1951-1953-1956-1959-1963-1966-1970-1974)

The following Tables, given for information purposes, contain details of a number of different monochrome television systems in use at the time of the XIIth Plenary Assembly of the C.C.I.R., New Delhi, 1970.



Frequency (MHz)

FIGURE 1

Significance of items 11 to 15 of Table I. The numbers in the diagram correspond to those of the items

B: channel limits
V: vision carrier
S: sound carrier

II-4. 3 Report 407-1(Rev72) Characteristics of Colour Television Systems

DRAFT

REPORT 407-1 (Rev.'72)

CHARACTERISTICS OF COLOUR TELEVISION SYSTEMS *

(Question 1/11)

(1966-1970-1974)

This Report describes the characteristics of the different colour television systems in use or under consideration at the time of the Interim Meeting of Study Group 11, Geneva, 1972.

Information on the results of the comparative laboratory tests carried out on the various colour television systems in the period 1963-1966 by broadcasting authorities, administrations and industrial organizations is given in Report 406.

A. CHARACTERISTICS OF THE NTSC COLOUR TELEVISION SYSTEM DERIVED FROM SYSTEM M **

1. **Video-frequency characteristics** (Table I of Report 308-2)

Number of lines per picture (frame):	525
Field frequency (fields/s):	59·94
Interlace:	2/1
Picture (frame) frequency (pictures/s):	29·97
Line frequency (lines/s):	15 734·264
Tolerance (lines/s):	± 0·044
Aspect ratio (width/height):	4/3
Scanning sequence (line):	Left-to-right
(field):	Top-to-bottom
System capable of operating independently of power supply frequency:	Yes
Approximate gamma of picture signal:	0·45 (1/2·2)
Nominal video bandwidth (MHz):	4·2
Chrominance sub-carrier frequency (MHz):	3·579545
Tolerance (Hz):	± 10

A burst of at least eight cycles at the frequency of the chrominance sub-carrier occurs during each horizontal blanking period after the line-synchronizing pulse and at least 0·006 *H* from the trailing edge of that pulse and lasts until not more than 0·125 *H* from the leading edge of the same line-synchronizing pulse. The zero axis of the colour-burst is at the blanking level and its peak-to-peak amplitude about the blanking level is from 0·90 to 1·1 of the difference between the levels of the synchronizing pulses and the blanking level.

This colour burst is omitted during the field-blanking period.

* Study Group XI was not able to issue a Recommendation for a single colour television system. The report by Sub-Group XI-A-2, which was asked to work out a solution to this problem at the XIth Plenary Assembly, Oslo, 1966, is annexed.

** These characteristics are those given in Doc. XI/128 (U.S.A.), 1963-1966.

monochrome television systems

	System						
	G	*H*	*I*	*D, K, K1* [1]	*L*	*F*[1]	*E* [1]
of line and field synchronizing signals respectively)							
	625	625	625	625	625	819	819
	50	50	50	50	50	50	50
	2/1	2/1	2/1	2/1	2/1	2/1	2/1
	25	25	25 ± 0·001%	25	25	25	25
	15 625 ± 0.02%	15 625 ± 0.02%	15 625 ± 0.0001% [13]	15 625 ± 3 Hz [14]	15 625 ± 0·1%	20 475 ± 0·1%	20 475
	4/3	4/3	4/3	4/3	4/3	4/3	4/3
	Left to right	Left to right	Left to right	Left to right	Left to right	Left to right	Left to right
	Top to bottom	Top to bottom	Top to bottom	Top to bottom	Top to bottom	Top to bottom	Top to bottom
	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	0·5	0·5	related to a gamma display of 2.8 ± 0.3	0·5	0·5	0·5	0·6
	2 to 3	2 to 3	2 to 3	2 to 3	2 to 3	2 to 3	2 to 3
	5	5	5·5	6	6	5	10

TABLE I — *Characteristics of*

Item	Characteristics	System				
		A (1)	*M* (2)	*N*	*D*	*C* (1)
		Radio-frequency characteristics (See also Table IV for ideal				
11	Nominal radio-frequency channel bandwidth (MHz)	5	6	6	7	7
12	Sound carrier relative to vision carrier (MHz)	− 3·5	+ 4·5	4·5	+ 5·5	+ 5·5
13	Nearest edge of channel relative to vision carrier (MHz).	+ 1·25	− 1·25	− 1·25	− 1·25	− 1·25
14	Nominal width of main sideband (MHz)	3	4·2	4·2	5	5
15	Nominal width of vestigial sideband (MHz)	0·75	0·75	0·75	0·75	0·75
16	Minimum attenuation of vestigial sideband (dB) (2)		20(−1·25 MHz) 42(−3·58 MHz)	20(−1·25 MHz) 42(−3·5 MHz)	20(−1·25 MHz) 20(−3·00 MHz) 30(−4·43 MHz)	
17	Type and polarity of vision modulation	A5C positive	A5C negative	A5C negative	A5C negative	A5C positive
18	Synchronizing level as percentage of peak carrier	< 3	100	100	100	< 3
19	Blanking level as a percentage of peak carrier	30	72·5-77·5	72·5-77·5	72·5-77·5	22·5-25·5
20	Difference between black level and blanking level as a percentage of peak carrier	0	2·875-6·75	2·875-6·75	0-2	3-6
21	Peak white level as a percentage of peak carrier	100	10-15	10-15	10-12·5	100
22	Type of sound modulation	A3	F3, ± 25 kHz 75 µs pre-emphasis	F3, ± 25 kHz 75 µs pre-emphasis	F3, ± 50 kHz 50 µs pre-emphasis	A3, 50 µs pre-emphasis
23	Ratio of effective radiated powers of vision and sound (3)	4/1	10/1-5/1 (4/1) (4)	10/1-5/1	10/1 (9)	4/1

(1) These systems are given for information only. They are not recommended for adoption by countries setting up a new television service (see Recommendation 470).

(2) In some cases, low-power transmitters are operated without vestigial sideband filters.

(3) The values to be considered are:
— the r.m.s. value of the carrier at the peak of the modulation envelope for the vision signal;
— the r.m.s. value of the unmodulated carrier for amplitude-modulated and frequency-modulated sound transmissions.

(4) The figures in brackets refer to the Japanese 525-line system.

(5) The figures in brackets refer to standard *K*1.

(6) The Administrations proposing standards *D* and *K* are studying the possibility of increasing the width of the vestigial sideband to 1·25 MHz.

(7) In the neighbourhood of − *fsc* (where *fsc* is the sub-carrier frequency) for transmitters that may transmit colour television signals. The precise values can be determined by further investigations.

(8) Applies to Systems *D* and *K* only.

(9) The Austrian Administration may continue to use a 5/1 power ratio in certain cases where necessary.

(10) This System is used both normally and reversed on the frequency scale in a tête-bêche arrangement .

monochrome television systems (continued)

System						
G	*H*	*I*	*D, K, K1* (*)	*L*	*F* (*)	*E* (*)
sideband characteristics of vision transmitters)						
8	8	8	8	8	7	14
+ 5·5	+ 5·5	6	+ 6·5	+ 6·5	+ 5·5	± 11·15 (10)
−1·25	− 1·25	− 1·25	− 1·25	− 1·25	− 1·25	± 2·83 (10)
5	5	5·5	6	6	5	10
0·75	1·25	1·25	0·75 (8) (1·25)	1·25	0·75	2
20(−1·25 MHz)	20(−1·75 MHz)	20(−3·00 MHz)	20(−1·25 MHz) (8)	20 (−2·50 MHz)		
20(−3·00 MHz) 30(−4·43 MHz)	20(−3·00 MHz) 30(−4·43 MHz)	30(−4·43 MHz)	30 (7) (8)	Not defined at −4·43 MHz		
A5C negative	A5C negative	A5C negative	A5C negative	A5C positive	A5C positive	A5C positive
100	100	100	100	< 6	< 3	< 3
72·5-77·5	72·5-77·5	76	72·5-77·5 (15)	30 ± 2	22·5-27·5	30
0-2	0-7	0 (Nominal)	0 - 4.5 (16)	0-7	3-6	5
10-12·5 F3, ± 50 kHz 50 µs pre-emphasis	10-12·5 F3, ± 50 kHz 50 µs pre-emphasis	20 (Nominal) F3, ± 50 kHz 50 µs pre-emphasis	10 F3, ± 50 kHz 50 µs pre-emphasis	100 A3, no pre-emphasis	100 A3, 50 µs pre-emphasis	100 A3, no pre-emphasis
10/1 (9)	5/1-10/1	5/1	2/1-5/1	8/1	4/1	4/1

(11) Doc. 11/118 (Netherlands), 1970-1973, proposes 0.01%/s for all systems.

(12) See Annex II.

(13) When the reference of synchronism is being changed, this may be relaxed to 15625 ± 0.01%.

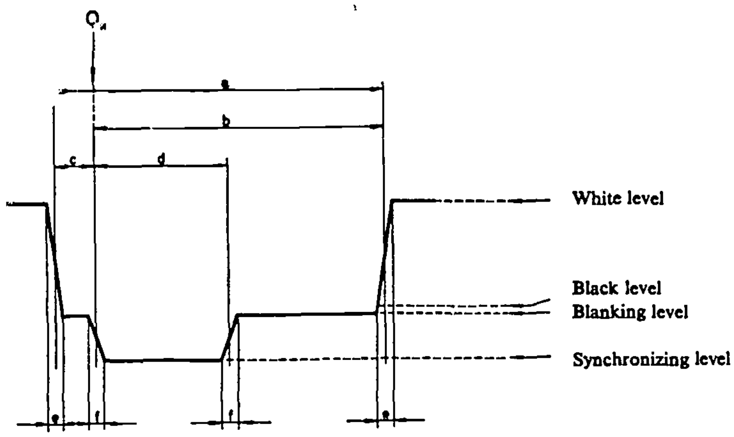
(14) Line-frequency tolerance:
(a) transmission of SECAM colour signals without subsequent conversion : + 3 Hz
(b) Line-duration tolerance : ± 0.05% from the mean value (± 32 ns).

(15) The blanking level in the radiated signal should not depart from the nominal value of this level by more than 2.5%; the nominal value is equal to 75% of the maximum amplitude of the carrier whatever the contents of the transmitted picture.

(16) In the video signal this corresponds to a pedestal level of 0 to 5% of the full video signal amplitude.

TABLE II

Details of line synchronizing signals



Item	Characteristics	Durations (measured between half-amplitude points on the appropriate edges) for system							
		A		*M*		*N*		*B, H, G* (¹)	
		% *H*	μs	% *H*	μs	% *H*	μs	% *H*	μs
H	Line period	100	98·8	100	63·5	100	64	100	64
a	Line blanking interval	17·7-19·2	17·5-19	16-18	10·2-11·4	16-18	10·24-11·52	18·5-[illegible] 2	11·8-12·3
b	Interval between time datum (O_H) and back edge of line blanking signal	16·2-17·2	16-17	14-16	8·9-10·2	14-16	8·96-10·24		
c	Front porch	1·52-1·95	1·5-2·0	2-4	1·27-2·54	2-4	1·28-2·56	2-[illegible]8	1·3-1·8
d	Synchronizing pulse	8·1-10·1	8-10	6·6-9	4·19-5·7	6·6-9	4·22-5·76	7-7·[illegible]	4·5-4·9
e	Build-up time (10-90%) of the edges of the line blanking signal	0·26-0·51	0·25-0·5	< 1	< 0·64	< 0·1	< 0·064	0·31-0·62	0·2-0·4
f	Build-up time (10-90%) of line synchronizing pulses	< 0·26	< 0·25	< 0·4	< 0·25	< 0·4	< 0·256	0·31-0·62	0·2-0·4

(¹) The primary values are those given in μs.

Durations (measured between half-amplitude points on the appropriate edges) for system											
C		*I*		*D, K, K1*		*L*		*F*		*E*	
% *H*	μs	% *H*	μs	% *H* (¹)	μs	% *H* (¹)	μs	% *H*	μs	% *H*	μs
100	64	100	64	100	64	100	64	100	48·84	100	48·84
18·7	11·8-12·2		12·05 ± 0·25	18·5-19·2	11·8-12·3	18·8	12·0 ± 0·3	18·4	9-9·4	19	9·2-9·8
16·5	10·2-11		10.4 ± 0.35	16·1-17·3(*)	10·3-11·3(*)	16·5	10·5 (mean value)	16·4	7·8-8·6	17·8	8·9
2·2	1·2-1·6		1.65 ± 0.1	2-2·8	1·3-1·8	2·3	1·5 ± 0·3	2	0·8-1·2	1·2	0·5-0·7
7·8	4·8-5·2		4·7 ± 0.1	7-7·7	4·5-4·9	7·3	4·7 ± 0·3	7·2	3·4-3·8	5·2	2·4-2·6
0·5	0·2-0·4		0·3 ± 0·1	0·31-0·62	0·2-0·4	0·5	0·3 ± 0·1	0·4	0·1-0·3	0·4	0·17-0·23
0·5	0·2-0·4		0.25 ± 0.05	0·23-0·46	0·15-0·3	0·25	0·15 ± 0·05	0·4	0·1-0·3	0·25	0·10-0·14

(*) Calculated values.
(¹) The values given in % *H* are rounded off.

TABLE III — *Detail*

Item	Characteristics	System A (% H)	A (µs)	M [5] (% H)	M [5] (µs)	N (% H)	N (µs)	B, H, G [6] (% H)	B, H, G [6] (µs)
V	Field period . . . . (ms)	20		16·667		20		20	
H	Line period . . . . (µs)	98·8		63·5		64		64	
j	Field-blanking period . . . (µs)	(13-15·5) H [2] + 18·25 [3]		(19-21) H + 10·7		(19-25) H + 10·84		25 H = 12 µs	
k [1]	Build-up times (10-90%) of the edges of field-blanking pulses (µs)	0·25-0·5		< 6·35		< 6·35		< 6	
l	Duration of first equalizing pulse sequence	[4]		3 H		3 H		2·5 H	
l'	Nominal interval between beginning of the field-blanking pulse and the leading edge of the field synchronizing pulse (O_v)								
m	Duration of synchronizing pulse sequence	4 H		3 H		3 H		2·5 H	
n	Duration of second sequence of equalizing pulses			3 H		3 H		2·5 H	
		% H	µs	% H	µs	% H	µs	% H	µs
p	Duration of equalizing pulse . . .			3·6-4	2·29-2·54	3·6-4	2·30-2·56	3·4-3·75	2·2-2·4
q	Duration of field synchronizing pulse	38·5-42·5	38-42	41·6-44	26·4-28	41·6-44	26·52-28·16		
r	Interval between field synchronizing pulses	11·5-7·5	11·4-7·4	6-8·8	3·8-5·6	6-8·8	3·84-5·63	7-7·7	4·5-4·9
s	Build-up times (10-90%) of the edges of synchronizing signals . .	< 0·26	< 0·25	< 0·4	< 0·25	< 0·4	< 0·25	0·31-0·62	0·2-0·4

(1) Not indicated on diagram.
(2) The coefficient of H is an integral multiple of 0·5.
(3) In reality, the value of a given in Table II.

System											
C		*I*		*D, K, K1*		*L*		*F*		*E*	
20		20		20		20		20		20	
64		64		64		64		48·84		48·84	
25 H = 12 µs		25 *H* + 12 µs		25 *H*		25 *H* + 12 µs		(29-30) *H* + 9		41 *H*	
< 6·4		0.3 ± 0.1		0·2-0·4		0·2-2		< 4·9		< 0·2	
2·5 *H*		2·5 *H*		2·5 or 3 *H*		2·5 *H*		3·5 *H*			
										3 *H*	
2·5 *H*		2·5 *H*		2·5 or 3 *H*		2·5 *H*		3·5 *H*			
2·5 *H*		2·5 *H*		2·5 or 3 *H*		2·5 *H*		3·5 *H*			
% *H*	µs	% *H*	µs	% *H* (6)	µs	% *H* (6)	µs	% *H*	µs	% *H*	µs
3·7	2·3-2·5		2·35 ± 0·1	3·5-3·85	2·25-2·45	3·7	2·35 ± 0·1	3·5	1·6-1·8		
42	26·8-27·2		27·3 ± 0.1			42·6	27·3 (mean value)	43	20·6-21	41	19-21
7·8	4·8-5·2		4·7 ± 0.1	7-7·7	4·5-4·9	7·3	4·7 ± 0·2	7·2	3·4-3·8		
0·5	0·2-0·4		0.25 ± 0.05	0·23-0·46	0·15-0·3	0·25	0·15 ± 0·05	0·4	0·1-0·3	< 0·4	< 0·2

(4) In the 405-line system there are no equalizing pulses; the field-blanking period commences in advance of the field-synchronizing pulse sequence by an interval of from 0·015 *H* to 0·515 *H*.

(5) The primary values are those given in µs.

(6) The values given in percentages of *H* are rounded off.

TABLE III A

Details of field-synchronizing waveforms

1. Diagrams applicable to all systems except *E* and *M*

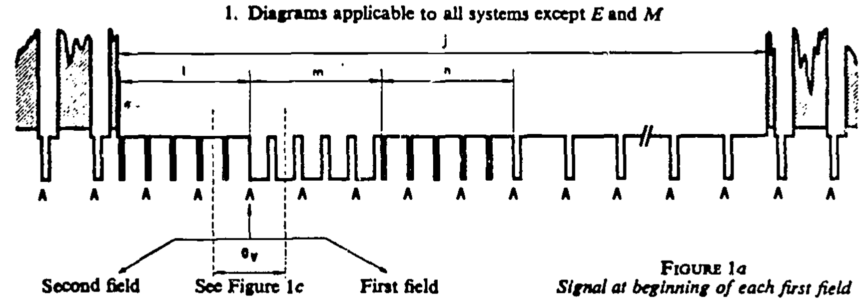


FIGURE 1*a*

Signal at beginning of each first field

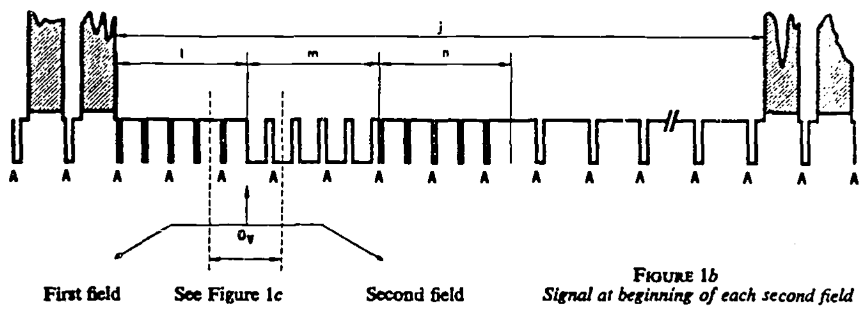


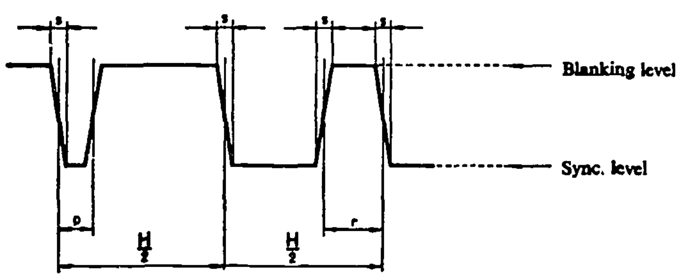
FIGURE 1*b*

Signal at beginning of each second field

Note 1. — $\wedge\wedge\wedge$ indicates an unbroken sequence of edges of line-synchronizing pulses throughout the field-blanking period.

Note 2. — At the beginning of each first field, the edge of the field-synchronizing pulse (O_V) coincides with the edge of a line-synchronizing pulse if *l* is an *odd* number of half-line periods as shown.

Note 3. — At the beginning of each second field, the edge of the field-synchronizing pulse (O_V) falls midway between the edges of two line-synchronizing pulses if *l* is an *odd* number of half-line periods as shown.



(The durations are measured to the half-amplitude points on the appropriate edges)

FIGURE 1*c*

Details of equalizing and synchronizing pulses

TABLE III B

Details of field-synchronizing waveforms

2. Diagrams applicable to system *E*

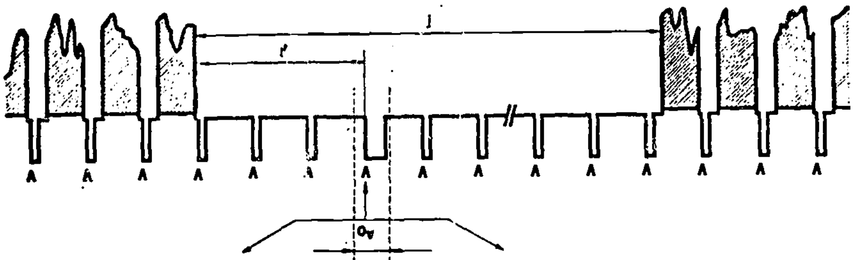


FIGURE 2a

Signal at beginning of each first field

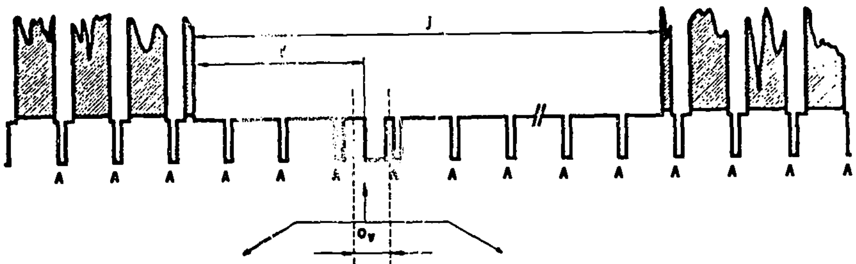


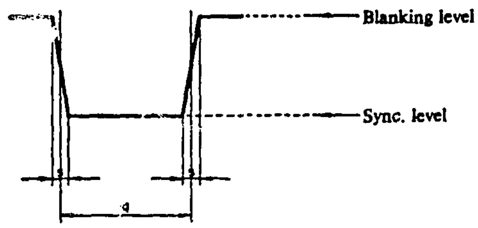
FIGURE 2b

Signal at beginning of each second field

Note 1. — ∧ ∧ ∧ indicates an unbroken sequence of edges of line-synchronizing pulses throughout the field-blanking period.

Note 2. — At the beginning of each first field, the edge of the field-synchronizing pulse (O_V) coincides with the edge of a line-synchronizing pulse.

Note 3. — At the beginning of each second field, the edge of the field-synchronizing pulse (O_V) falls midway between the edges of two line-synchronizing pulses.



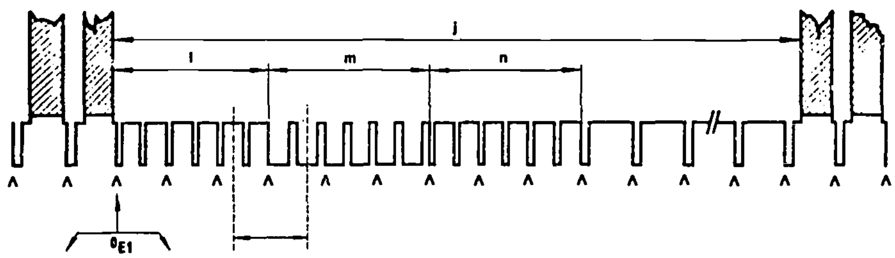
(The durations are measured to the half-amplitude points on the appropriate edges)

FIGURE 2c

Details of equalizing and synchronizing pulses

TABLE III C

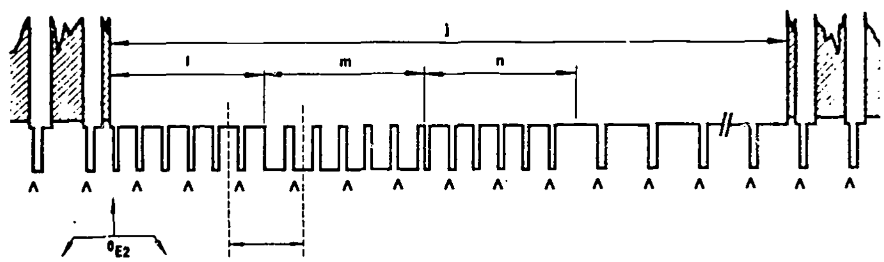
Diagrams applicable to system *M*



Second field First field See Figure 3*c*

FIGURE 3*a*

Signal at beginning of each first field



First field Second field See Figure 3*c*

FIGURE 3*b*

Signal at beginning of each second field

Note 1. — ∧ indicates an unbroken sequence of edges of line-synchronizing pulses throughout the field-blanking period.

Note 2. — Field-one line numbers start with the first equalizing pulse in Field 1, designated O_{E1} in Fig. 3*a*.

Note 3. — Field-two line numbers start with the second equalizing pulse in Field 2, one-half-line period after O_{E2} in Fig. 3*b*.

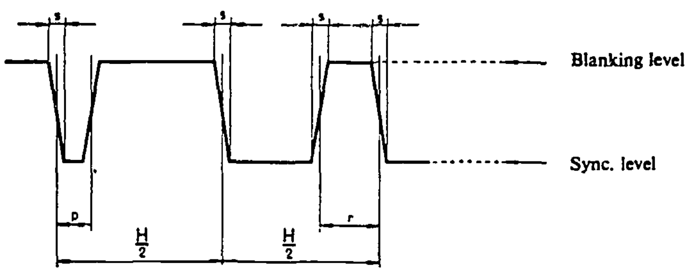


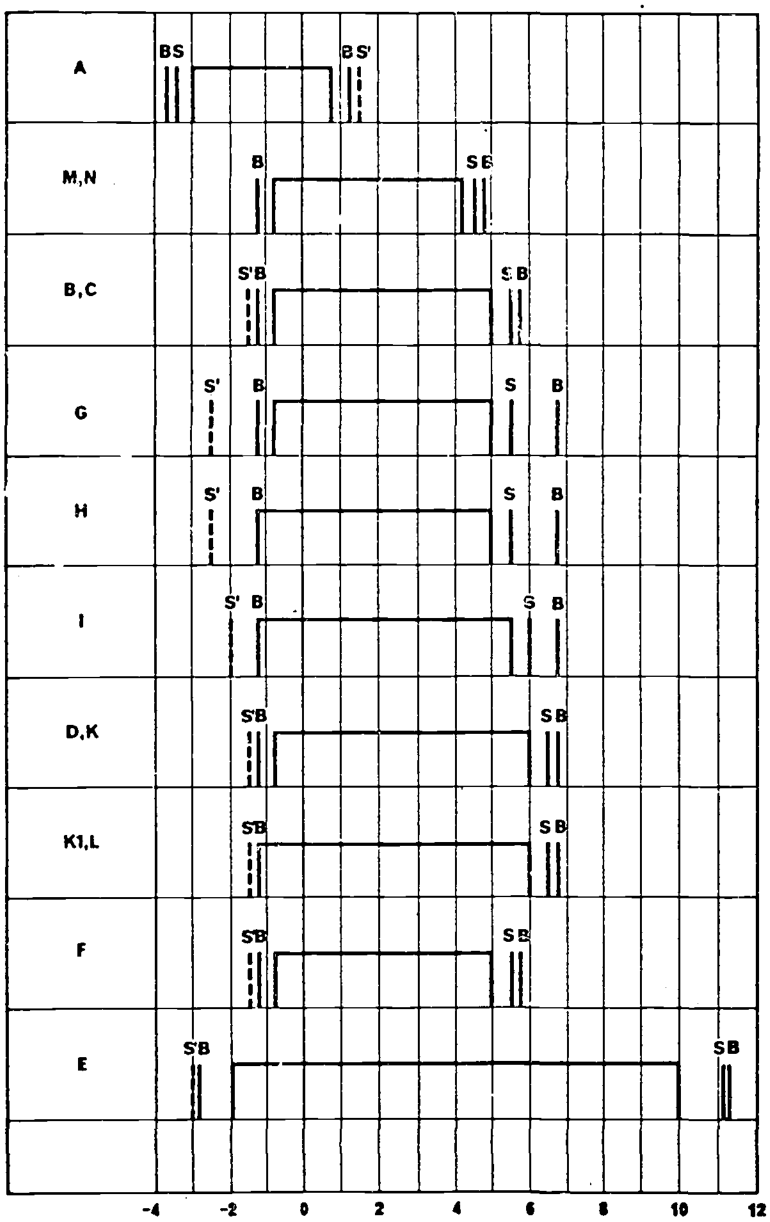
FIGURE 3c

Details of equalizing and synchronizing pulses

(The durations listed in Table III relate to the half-amplitude points on the appropriate edges)

TABLE IV

Ideal amplitude-frequency characteristics for vision transmitters
(See Table I for precise frequency spacings)



System-frequency (MHz) relative to the vision carrier frequency

S : sound carrier
S': sound carrier of the lower adjacent channel (upper channel in system *A*)
B : nominal limits of channel

ANNEX I

SYSTEMS USED IN VARIOUS COUNTRIES

Explanation of signs used in the list :

* : planned (whether the standard is indicated or not);

- : not yet planned, or no information received.

NOTES TO LIST

Note 1.- Austria reserves the right to the possible use of additional frequency-modulated sound carriers, in the band between 5.75 and 6.75 MHz, in relation to the picture carrier.

Note 2.- The Indications and Notes are based on indications and notes given in Chapter 2 of the "Technical data used by the European VHF/UHF Broadcasting Conference".

Note 3.- No definite decision has been taken about the width of the residual sideband, but this country is willing to accept the assumption that for planning purposes the residual sideband will be 0.75 MHz wide.

Note 4.- System I will be used at all stations. In addition, during a transition period, transmissions on system A will be made from the Dublin and Sligo stations.

Note 5.- This country does not at present intend to use bands IV and V, but accepts the parameters given in the table under "Standard G" as television standard in bands IV and V.

Note 6.- No final decision has been taken about the width of the residual sideband, but for planning purposes this country is willing to accept the assumption of a residual sideband 1.25 MHz wide.

Note 7.- The Swiss Administration is planning to use additional frequency-modulated sound carriers, in the frequency interval between the spacings of 5.5 and 6.5 MHz in relation to the picture carrier, at levels lower than or equal to the normal level of the sound carrier, for additional sound-tracks or for sound broadcasting.

Note 8.- Liberia accepted for planning purposes Standard B or H but reserves the right to adopt standard M.

Note 9.- Uganda is already committed to Standard B in band III. Standard G is planned for bands IV and V although further consideration will be given to other standards when bands IV and V stations are to be commissioned.

Note 10.- Indications for Malawi, Rhodesia and Zambia are based on indications for Rhodesia and Nyasaland (Federation of) given in the Final Acts of the African VHF/UHF Broadcasting Conference, Geneva, 1963. Standard B is now in use in band I; no final decision is taken regarding systems to be used in bands III, IV and V.

Note 11.- Sierra Leone now uses Standard B but reserves the right to use any other standard compatible with the Plan.

Note 12.- Tanzania, the indications are based on indications for Tanganyika and Zanzibar given in the Final Acts of the African VHF/UHF Broadcasting Conference, Geneva, 1963. It is intended to use Standard B in bands I and III. Although Standard I is planned for bands IV and V, further consideration will be given to the use of Standards G and H.

Note 13.- Algeria reserves the right to change later.

Note 14.- The Arab Republic of Egypt is now studying the adoption of either Standard G or H for bands IV and V.

Note 15.- In Cameroon, Zaïre (Republic of) and Guinea, planning has been based on Standard K1, but they reserve the right to use any other standard compatible with the Plan when they introduce television.

Note 16.- The indications and Notes 10-17 are based on indications and Notes given in the Final Acts of the VHF/UHF African Broadcasting Conference, Geneva, 1963.

Note 17.- Belgium will use Standard C in bands I and III until November 1976, after which Standard B will be used.

Note 18.- Cyprus is already committed to the use of Standard B in band III. Standard H is envisaged for use in bands IV and V, although further consideration will be given to the possible use of other standards when stations operating in bands IV and V are to be commissioned.

Note 19.- In Kuwait, if the services are called upon to broadcast in a second language, the frequencies between 5.5 MHz and 6.5 MHz could be used to provide an additional frequency-modulation sub-carrier.

Note 20.- Singapore reserves the right to use additional frequency-modulation sound channels in the band between 5.5 and 6.5 MHz in relation to the picture carrier, for additional sound channels for sound broadcasting.

Note 21.- Some existing transmitters operate with a residual sideband up to 1.25 MHz. For the future, only transmission with a residual sideband of 0.75 MHz is foreseen.

COUNTRY	System used in bands		Number of Note for bands	
	I-III	IV-V	I-III	IV-V
British East Africa	B*	-		
Algeria (Algerian Democratic and Popular Republic)	B, E	G*,H*	13,16	13,16
Netherlands Antilles	M	-		
Saudi Arabia (Kingdom of)	B	-		
Argentine Republic	N	N*		
Australia (Commonwealth of)	B	-		
Austria	B	G		1
Belgium	C,B	H	17	
Brazil	M	M		
People's Republic of Bulgaria	D	K*		
Burundi (Republic of)	K1*	K1*	16	16
Cameroon (Fed.Republic of)	K1*	K1*	15,16	15,16
Canada	M	M		
Central African Republic	K1*	K1*	16	16
Ceylon	B	-		
Cyprus (Republic of)	B	H*		2,18
Colombia	M	M*		
Congo (Republic of the) (Brazzaville)	K1*	K1*	16	16
Cuba	M	M		
Korea (Republic of)	M	-		
Ivory Coast (Republic of the)	K1*	K1*	16	16
Dahomey (Republic of)	K1*	K1*	16	16
Denmark	B	G*		
Egypt (Arab Republic of)	B	G*,H*	16	14,16
Group of Territories represented by the French Overseas Post and Telecommunication Agency	K1	-	-	-

COUNTRY	System used in bands		Number of Note for bands	
	I-III	IV-V	I-III	IV-V
Spain	B	G*		2
United States of America	M	M		
Ethiopia	B*	G*	16	16
Finland	B	G		3
France	E	L		
Gabon Republic	K1*	K1*	16	16
Ghana	B*,G*	G*	16	16
Greece	B*	G*		3
Guinea (Republic of)	K1*	K1*	15,16	15,16
Upper Volta (Republic of)	K1*	K1*	16	16
Hungarian People's Republic	D	K*		
India (Republic of)	B	-		
Indonesia (Republic of)	B*	-		
Iran	B	G		
Ireland	A,I	I*	4	
Iceland	-	G*		2,5
Israel (State of)	B	G		6
Italy	B	G		
Jamaica	N	-		
Japan	M	M		
Jordan	B	G*		
Kenya	B*	G*,I*	16	16
Kuwait (State of)	B	G*		19
Liberia (Republic of)	B*	H*	8,16	8,16
Libyan Arab Republic	B*	G*	16	16
Luxembourg	C	L*		2
Malaysia	B	G*		
Malawi	B*	G*	10,16	10,16
Malagasy Republic	K1*	K1*	16	16
Mali (Republic of)	K1*	K1*	16	16
Morocco (Kingdom of)	B	H*		
Mauritius	B	-		
Mauritania (Islamic Republic of)	K1*	K1*	16	16
Mexico	M	-		
Monaco	E	L*		
Niger (Republic of the)	K1*	K1*	16	16
Nigeria (Fed.Republic of)	B	I*	16	16
Norway	B	G*		3
New Zealand	B	-		
Uganda	B	G*	9,16	9,16
Pakistan	B	-		
Panama	M	-		

COUNTRY	System used in bands		Number of Note for bands	
	I-III	IV-V	I-III	IV-V
The Netherlands (Kingdom of)	B	G		21
People's Republic of Poland	D	K		
Portugal	B	G		
Peru (Republic of)	M	M		
Spanish Provinces in Africa	B*	G*	16	16
Portuguese Oversea Provinces	I*	I*	16	16
German Democratic Republic ◆	B	G		
Federal Republic of Germany	B	G		
Somali Republic	B*	G*	16	16
Rhodesia	B	G*	10	10
Roumanian Socialist Republic	D	K*		2
United Kingdom	A	I		
Rwanda (Republic of)	K1*	K1*	16	16
Senegal (Republic of the)	K1*	K1*	16	16
Sierra Leone	B	G*	11,16	16
Singapore	B	G*		20
South Africa (Republic of)	I*	I*	16	16
Sweden	B	G		
Switzerland (Confederation of)	B	G*		2,7
Tanzania (United Republic of)	B*,I*	I*	12,16	12,16
Chad (Republic of the)	K1*	K1*	16	16
Czechoslovak S.R.	D	K*		2
Oversea Territories in Africa for the international relations of which the Government of the United Kingdom of Great Britain and Northern Ireland are responsible	B*,I*	I*	16	16
Oversea Territories of the United Kingdom in the European Broadcasting Area	-	H*		2
Togolese Republic	K1*	K1*	16	16
Turkey	B	G*		
U.S.S.R.	D	K		
Uruguay (Oriental Republic of)	N	-		
Venezuela (Republic of)	M	-		
Yugoslavia (Fed. Socialist Rep. of)	B	H		
Zaïre (Republic of)	K1*	K1*	15,16	15,16
Zambia (Republic of)	B*	G*	10,16	10,16

◆ Publication of information marked with this symbol implies no recognition by the Union of the status of the sender in relation thereto.

ANNEX II

DEFINITION OF GAMMA AND GAMMA PRE-CORRECTION

The gamma of the picture-tube is defined as the slope of the curve giving the logarithm of the luminance reproduced as a function of the logarithm of the video signal voltage when the brightness control of the receiver is set so as to make this curve as straight as possible in a luminance range corresponding to a contrast of at least 1/40.

Pre-correction is intended to compensate for the non-linearities of the transfer characteristics of picture tubes in a luminance range corresponding to a contrast of at least 1/40. It is assumed that the transfer characteristic of the picture tube follows a power law whose exact exponent is still under study.

BIBLIOGRAPHY

1. C.C.I.R., Doc. 11/78 (Netherlands) 1970-1973.
2. C.C.I.R., Doc. 11/81 (Federal Republic of Germany) 1970-1973.

1.1 *Composition of the colour-picture signal*

1.1.1 $$E_M = E'_Y + \left[E'_Q \sin(\omega t + 33°) + E'_I \cos(\omega t + 33°) \right]$$

where

$$E'_Q = 0{\cdot}41\,(E'_B - E'_Y) + 0{\cdot}48\,(E'_R - E'_Y).$$
$$E'_I = -0{\cdot}27\,(E'_B - E'_Y) + 0{\cdot}74\,(E'_R - E'_Y).$$
$$E'_Y = 0{\cdot}30\,E'_R + 0{\cdot}59\,E'_G + 0{\cdot}11\,E'_B.$$

For colour-difference frequencies below 500 kHz (see § 1.1.2), the signal

$$E_M = E'_Y + \left\{ \frac{1}{1{\cdot}14} \left[\frac{1}{1{\cdot}78} (E'_B - E'_Y) \sin \omega t + (E'_R - E'_Y) \cos \omega t \right] \right\}$$

where

E_M is the total video voltage, corresponding to the scanning of a particular picture element, applied to the modulator of the picture transmitter.

E'_Y is the gamma-corrected voltage of the monochrome portion of the colour picture signal, corresponding to the given picture element.

E'_Q and E'_I are the amplitudes of two orthogonal components of the chrominance signal corresponding respectively to narrow-band and wideband axes.

E'_R, E'_G, and E'_B are the gamma-corrected voltages corresponding to red, green and blue signals during the scanning of the given picture element.

ω is the angular frequency and is 2π times the frequency of the chrominance sub-carrier.

The portion of each expression between brackets in § 1.1 represents the chrominance sub-carrier signal which carries the chrominance information.

The phase reference in the E_M equation in § 1.1 is the phase of the burst + 180°. The burst corresponds to amplitude-modulation of a continuous sine-wave.

1.1.2 The equivalent bandwidths assigned prior to modulation to the colour difference signals E'_Q and E'_I are as follows:

Q-channel bandwidth:

at 400 kHz, less than 2 dB down;
at 500 kHz, less than 6 dB down;
at 600 kHz, at least 6 dB down.

I-channel bandwidth:

at 1·3 MHz, less than 2 dB down;
at 3·6 MHz, at least 20 dB down.

1.1.3 The gamma-corrected voltages, E'_R, E'_G, and E'_B, are suitable for a colour picture tube having primary colours with the following chromaticities in the C.I.E. system of specification:

	x	y
Red (*R*)	0·67	0·33
Green (*G*)	0·21	0·71
Blue (*B*)	0·14	0·08

and having a transfer gradient (gamma exponent) of 2·2 associated with each primary colour. The voltages E'_R, E'_G and E'_B may be respectively of the form $E_R^{1/\gamma}$, $E_G^{1/\gamma}$ and $E_B^{1/\gamma}$, although other forms may be used with advances in the state of the technique.

1.1.4 The radiated chrominance sub-carrier vanishes on the reference white of the scene.

Note. — The numerical values of the signal specification assume that this condition will be reproduced as standard illuminant C ($x = 0{\cdot}310$, $y = 0{\cdot}316$) of the International Lighting Commission (C.I.E.).

1.1.5 E'_Y, E'_Q, E'_I and the components of these signals match each other in time to 0·05 μs.

1.1.6 The angle of the sub-carrier measured with respect to the burst phase, when reproducing saturated primaries and their complements at 75% of full amplitude, are within ± 10° and their amplitudes are within ± 20% of the values specified above. The ratios of the measured amplitudes of the sub-carrier to the luminance signal for the same saturated primaries and their complements fall between the limits of 0·8 and 1·2 of the values specified for their ratios.

2. Radio-frequency characteristics (Table I of Report 308-2)

Nominal radio-frequency bandwidth (MHz):	6
Sound-carrier relative to vision-carrier (MHz):	+ 4·5
Nearest edge of channel relative to vision carrier (MHz):	− 1·25
Nominal width of main sideband (MHz):	4·2
Nominal width of vestigial sideband (MHz):	0·75
Type of polarity of vision modulation:	A5C, negative
Synchronizing level as a percentage of peak carrier:	100
Blanking level as a percentage of peak carrier:	72·5–77·5
Difference between black level and blanking level as a percentage of peak carrier:	2·875–6·75
Peak-white level as a percentage of peak carrier:	10–15
Type of sound modulation:	F3, ± 25 kHz 75 μs pre-emphasis
Ratio of effective radiated powers of vision and sound:	10/1–5/1

3. Details of line-synchronizing signals (Table II of Report 308-2)

	%H	μs
Line period (H):	100	63·556
Line-blanking interval (a):	16·5–18	10·5–11·4
Interval between time datum (H_o) and back edge of line-blanking signal (b):	12·7–16	8·06–10·3
Front porch (c):	⩾ 2	⩾ 1·27

	%H	μs
Synchronizing pulse (d):	6·6–8	4·2–5·1
Build-up time (10–90%) of the edges of the line-blanking signal (e):	⩽ 0·75	⩽ 0·48
Build-up time (10–90%) of line-synchronizing pulses (f):	⩽ 0·4	⩽ 0·25

4. **Details of synchronizing signal** (Table III of Report 308-2)

Field period (V):	16·683
Line period (H) (μs):	63·556
Field-blanking period (j) (μs):	1168–1335 (0·07–0·08) V Approx. (18–21) H
Build-up times (10–90%) of the edges of field-blanking pulses (k) (μs):	⩽ 6·36
Duration of first equalizing pulse sequence (l):	3 H
Duration of synchronizing pulse sequence (m):	3 H
Duration of second sequence of equalizing pulses (n):	3 H

	%H	μs
Duration of equalizing pulse (p):	3·6	2·29
Duration of field-synchronizing pulse (q):	41·6–44	26·4–28·0
Interval between field-synchronizing pulses (r):	6–8·8	3·8–5
Build-up times (10–90%) of edges of synchronizing signals (s):	⩽ 0·4	⩽ 0·25

B. CHARACTERISTICS OF THE PAL COLOUR TELEVISION SYSTEMS DERIVED FROM SYSTEMS M, B, G, H AND I

SPECIFICATION OF THE PAL SYSTEM: OCTOBER, 1967

TABLE I

Characteristics

(For tolerances suggested for radiated signals, see Table II)

Item	Characteristics	Systems (1)		
		I-PAL	B-PAL, G-PAL and H-PAL	M-PAL
1	General specification			
	Luminance component	Amplitude modulation of the picture carrier		
	Chrominance component	Simultaneous pair of components transmitted as amplitude-modulated sidebands of a pair of suppressed sub-carriers in quadrature having a common frequency		
2	Colour sub-carrier frequency, f_{sc}	f_{sc} = 4433618·75 Hz		f_{sc} = 3575611·49 Hz
3	Frequency spectrum of composite colour vision and sound signals			
	Vision-to-sound spacing	6 MHz − 400 Hz = 5·9996 MHz	5·5 MHz	4·5 MHz
	Main sideband	5·5 MHz	5·0 MHz	4·2 MHz
	Vestigial sideband	1·25 MHz	0·75 MHz (3)	0·75 MHz
	Chrominance sidebands (2) E'_U signal, E'_V signal	f_{sc} { + 1·07 MHz, − 1·3 MHz } nominal	f_{sc} { + 0·57 MHz, − 1·3 MHz } nominal	f_{sc} { + 0·6 MHz, − 1·3 MHz } nominal

(1) Monochrome systems, the characteristics of which are given in Table I of Report 308-2.
(2) See Item 8.
(3) System H has a vestigial sideband of 1·25 MHz.

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Characteristics</th><th colspan="3">Systems</th></tr>
<tr><th>I-PAL</th><th>B-PAL, G-PAL and H-PAL</th><th>M-PAL</th></tr>
<tr><td rowspan="7">4</td><td rowspan="7">Synchronizing and blanking waveform

Colour synchronization</td><td colspan="3">Complies with Report 308-2 with the following modifications:</td></tr>
<tr><td colspan="2">Sub-carrier burst — Duration: 10 cycles</td><td>9 cycles</td></tr>
<tr><td colspan="2">Start: 5·6 µs after the leading edge O_H of the line-sync. pulses.
See u in Fig. 1.</td><td>5·8 µs after the leading edge O_H of line-sync. pulses.
See u in Fig. 1.</td></tr>
<tr><td colspan="3">Peak-to-peak value:
3/7 of the difference between white and blanking levels (equal to nominal video-sync. pulse magnitude prior to transmission (4)). See Z in Fig. 1.</td></tr>
<tr><td colspan="3">Phase sequence relative to the $+E'_U$ axis taken as the phase reference:
On odd lines of the first and second fields and on even lines of the third and fourth fields, the phase of burst is +135°, see B_1 in Fig. 1.
On even lines of the first and second fields and on odd lines of the third and fourth fields, the phase of the burst is −135°, see B_2 in Fig. 1.</td></tr>
<tr><td colspan="3">Blanking:</td></tr>
<tr><td colspan="2">the colour bursts shall be omitted during 9 lines of each field-blanking interval in the manner shown in Fig. 2*a*.</td><td>the colour bursts shall be omitted during 11 lines of each field-blanking interval in the manner shown in Fig. 2*b*.</td></tr>
</table>

(4) The phrase "prior to transmission" is used to avoid taking into account the differences between the systems (I, B, G and H) in the transmitted ratio of picture signal amplitude to synchronizing signal amplitude. The magnitude of the video-synchronizing pulse prior to transmission is taken to be 3/7 of that of a transition from blanking level to white.

Item	Characteristics	Systems: I-PAL	Systems: B-PAL, G-PAL and H-PAL	Systems: M-PAL
5	Pre-correction at the transmitter for receiver group-delay characteristics.	none	$-0{\cdot}17$ µs at f_{sc} relative to low video frequencies (4)	see Fig. 3(b)
6	Scanning Line-scanning frequency, f_H	$f_H = 4f_{sc}/(1135 + 4/625)$		$f_H = 4f_{sc}/909$
7	Equation of colour picture signal E_M = total video picture signal voltage E'_Y = voltage of luminance component of E_M E'_R, E'_G and E'_B = gamma-precorrected voltages corresponding to the red, green and blue signals.	$E_M = E'_Y + E'_U \sin \omega_{sc}t \pm E'_V \cos \omega_{sc}t$ where $E'_Y = 0{\cdot}299E'_R + 0{\cdot}587E'_G + 0{\cdot}114E'_B$ $E'_U = 0{\cdot}493(E'_B - E'_Y)$ $E'_V = 0{\cdot}877(E'_R - E'_Y)$ The sign before $E'_V \cos \omega_{sc}t$ is positive during odd lines of the first and second fields and during even lines of the third and fourth fields as in item 4 (colour synchronization). (A display gamma of about 2·8 is assumed) (6)		
8	Bandwidth of video colour-difference signals: E'_U and E'_V	at 1·3 MHz < 3 dB down at 4 MHz > 20 dB down		at 1·3 MHz < 2 dB down at 3.6 MHz > 20 dB down
9	C.I.E. (1931) primary colour chromaticities of picture tube for which E'_R, E'_G and E'_B are suitable.	red ($x = 0{\cdot}64$ $y = 0{\cdot}33$) green ($x = 0{\cdot}29$ $y = 0{\cdot}60$) blue ($x = 0{\cdot}15$ $y = 0{\cdot}06$) Chromaticity for $E'_R = E'_G = E'_B$ shall match that of illuminant D 6500 ($x = 0{\cdot}313$ $y = 0{\cdot}329$)	red ($x = 0{\cdot}67$ $y = 0{\cdot}33$) green ($x = 0{\cdot}21$ $y = 0{\cdot}71$) blue ($x = 0{\cdot}14$ $y = 0{\cdot}08$) Chromaticity for $E'_R = E'_G = E'_B$ shall match that of illuminant C ($x = 0{\cdot}310$ $y = 0{\cdot}316$)	

(4) In the Netherlands, the specification of the pre-correction at the transmitter for receiver group-delay characteristics is as follows: a sinewave introduced at those terminals of the transmitter, which are normally fed by the encoded colour video signal, shall produce a radiated signal having an envelope delay, relative to the average envelope delay between 0·05 MHz and 0·20 MHz as indicated in the Table and Fig. 3. From Doc. XI/170 (Spain), 1966-1969, it is learned that this same group delay correction is used for transmitters in Spain.

(6) Pending additional studies, see Annex II to draft Report 308-2(Rev.'72).

TABLE II

Suggested tolerances for radiated signals

Number of item in main spec.	Number of item in tolerance spec.	Characteristics	Suggested tolerances for radiated signal		
			System *I*	Systems *B*, *G* and *H*	System *M*
2	i	Colour sub-carrier frequency:	4433618·75 Hz ± 1 Hz (1)	4433618·75 Hz ± 5 Hz	3575611·49 Hz ± 10 Hz
4	ii	Duration of sub-carrier burst:	10 cycles ± 1 cycle (2·25 μs ± 0·23 μs)		9 cycles ± 1 cycle (2·52 μs ± 0·28 μs)
4	iii	Start of sub-carrier burst:	5·6 μs ± 0·1 μs (4) after epoch O_H		5·8 μs ± 0·1 μs after epoch O_H
4	iv	Peak-to-peak value of sub-carrier burst: equal to nominal video-sync. pulse magnitude prior to transmission (2). See Fig. 1 (3).	± 10% of nominal video-sync. pulse magnitude prior to transmission (3)		
4	v		Amplitudes of bursts on successive lines shall not differ by more than 5% of the greater. See Fig. 1.		
4	vi	Mean value of phase angle of bursts: 180° with respect to axis of phase reference E'u (Fig.1)	$\pm 2^0$		0
4	vii	Phase angle of successive bursts ± 45° with respect to mean phase	$\pm 0.5^0$		$\pm 1^0$
7	viii	Colour picture signal: $E_M = E_Y' + E_U' \sin(\omega_{sc}t) \pm E_V' \cos(\omega_{sc}t \pm \theta)$	$0 = 1°$ (See Fig. 1)		

(1) This tolerance may not be maintained during such operational procedures as "gen-lock".

(2) The phrase "prior to transmission" is used to avoid taking into account the differences between the systems (*I*, *B*, *G* and *H*) in the transmitted ratio of picture signal amplitude to synchronizing signal amplitude. The magnitude of the video-synchronizing pulse prior to transmission is taken to be 3/7 of that of the picture signal.

(3) For the use of automatic gain control circuits, it is important that the burst amplitude should maintain the correct ratio with the chrominance signal amplitude.

(4) Transmitter pre-correction for receiver group delay is not included.

C. CHARACTERISTICS OF THE SECAM III COLOUR TELEVISION SYSTEM

The main technical parameters of the colour television broadcasting system which is compatible with all 625-line black-and-white television systems except N are given below.

1. Main characteristics of the picture analysis

The main characteristics of the analysis are the same as in the C.C.I.R. 625-line black-and-white television systems. (See Report 308-2.)

2. Characteristics of the composite video signal (at the transmitter input)

2.1 The composite video signal contains the luminance signal and the chrominance signal. The spectrum of the chrominance signal lies within the limits of the spectrum of the luminance signal.

2.2 The luminance signal E'_Y corresponds to the expression:

$$E'_Y = 0{\cdot}299\, E'_R + 0{\cdot}587\, E'_G + 0{\cdot}114\, E'_B$$

where:

$$E'_R = E_R^{1/\gamma};\ E'_G = E_G^{1/\gamma};\ E'_B = E_B^{1/\gamma},$$

E_R, E_G, E_B: are the video signals for the primary colours red, green and blue.

γ: is the exponent of the transfer characteristics of the receiver tube as a function of the signal voltage and is approximately 2·2.

2.3 The signals E_R, E_G and E_B correspond to the primary colours of a receiver with the following chromaticity coordinates (C.I.E. x-y system – 1931).

— red	$x = 0{\cdot}67$	$y = 0{\cdot}33$
— green	$x = 0{\cdot}21$	$y = 0{\cdot}71$
— blue	$x = 0{\cdot}14$	$y = 0{\cdot}08$

The reference illuminant corresponding to equality of the primary signals, $E'_R = E'_G = E'_B$, is the illuminant C

$$x = 0{\cdot}310 \qquad y = 0{\cdot}316$$

The maximum luminance value corresponds to the unit value of the signals E'_R, E'_G and E'_B.

2.4 The chrominance signal is a sub-carrier frequency-modulated sequentially line-by-line by two colour-difference signals.

2.5 The colour-difference signals correspond to the expressions:

$$D'_R = -1{\cdot}9\,(E'_R - E'_Y)$$

$$D'_B = 1{\cdot}5\,(E'_B - E'_Y)$$

Note. — The coefficients mentioned in §§ 2.2, 2.3 and 2.5 could be changed if more favourable luminophores were chosen for the receiver tube. See also Annex II to draft Report 308-2(Rev.'72).

2.6 During transmission of C.I.E. type C white-source chrominance signals ($E'_R = E'_G = E'_B$), the colour-difference signals D'_R and D'_B are nil.

2.7 The colour-difference signals D'_R and D'_B are low-frequency pre-corrected before modulation of the sub-carrier by means of a network with a transmission factor expressed by the formula:

$$A_{BF}(f) = [1 + j\,(f/f_1)] / [1 + j\,(f/3f_1)]$$

where f is the frequency (kHz)

$f_1 = 85$ kHz.

The colour-difference signals also have their spectrum limited by means of a filter the attenuation of which must not be less than 20 dB at frequencies equal to or higher than 3·0 MHz.

The overall nominal transmission factor resulting from pre-correction and limitation of the spectrum is shown in Fig. 4.

2.8 The sub-carrier is frequency-modulated by pre-emphasized signals, the spectrum of which is limited as described in § 2.7, i.e. by D'^*_R and D'^*_B.

The equation of the modulated chrominance signal for constant values of the signals D'^*_R and D'^*_B is:

$$m(t) = M \cos 2\pi . (f_0 + D'^* . \Delta f_0) . t$$

in which f_0, Δf_0 and D'^* are, respectively:

— the frequency corresponding to the absence of chrominance components f_{OR}, the nominal deviation Δf_{OR} and the pre-emphasized signal D'^*_R for the line D'_R;

— the frequency corresponding to the absence of chrominance components f_{OB}, the nominal deviation Δf_{OB} and the pre-emphasized signal D'^*_B for the line D'_B.

The nominal values of the frequencies (kHz) corresponding to the absence of chrominance components and of the deviations are as follows:

$f_{OR} = 4406{\cdot}25$ ($\pm$ 2 kHz) $\Delta f_{OR} = 280$

$f_{OB} = 4250{\cdot}00$ ($\pm$ 2 kHz) $\Delta f_{OB} = 230$

The maximum frequency deviation Δf_0 (kHz) is limited to the following nominal values:

$+350$ and -500 for the lines D'_R

$+500$ and -350 for the lines D'_B

This limitation occurs at the transitions to the excess values introduced on D'^*_R and D'^*_B by the pre-correction specified in § 2.7.

2.9 At the beginning of the line, the frequencies corresponding to the absence of chrominance components are controlled so that they are either in the same phase as, or in phase opposition to, a permanent sinusoidal signal of frequency:

$$f_{RR} = 282 . f_H = (282 \times 15\,625)\ \text{Hz} \quad \text{for } f_{OR}$$

$$f_{BB} = 272 . f_H = (272 \times 15\,625)\ \text{Hz} \quad \text{for } f_{OR}$$

A phase change of 180° is carried out during one line at every third line and additionally at every alternate field, producing the cycle 0–0–180° at odd fields and 180°–180°–0 at even fields.

2.10 The chrominance signal is subject to a high-frequency amplitude pre-correction by means of a corrective network with a transmission factor expressed by the formula:

$$A_{HF}(f) = (1 + j . 16F) / (1 + j . 1{\cdot}26F)$$

$$\text{where } F = f/f_0 - f_0/f \text{ and } f_0 = 4286{\cdot}00\ \text{kHz}$$

The nominal curve of the high-frequency correction is shown in Fig. 5.

2.11 The nominal peak-to-peak amplitude of the colour sub-carrier at the minimum transmission factor of the high-frequency corrective network specified in § 2.10 is 23% of that of the luminance signal.

2.12 The colour synchronizing signals (line identification) required for synchronous operation of the receiving and transmitting switches are transmitted during 9 lines of the field blanking interval, i.e. on lines 7 to 15 in the first field and 320 to 328 in the second field.

These identification lines are made by the colour sub-carrier which is frequency-modulated sequentially by the signals:

— D'_R varying trapezoidally, linear at the beginning of the line for 15 ± 5 μs between 0 and $+1{\cdot}25$ followed by a porch at the level $+1{\cdot}25 \pm 0{\cdot}13$;

— D'_B varying trapezoidally, linear at the beginning of the line for 20 ± 10 μs between 0 and $-1{\cdot}50$ followed by a porch at the level $-1{\cdot}50 \pm 0{\cdot}15$.

The colour synchronizing signals have the appearance shown in Figs. 6 (*a*) and 6 (*b*) before modulation of the sub-carrier and the appearance shown in Fig. 6 (*c*) after its modulation.

2.13 The chrominance signal is suppressed:

— during a time interval of 6·7 to 7·8 μs beginning with the line blanking signal;

— during a time interval beginning with the field blanking signal but excluding the transmission time of the colour synchronizing signals defined in § 2.12.

2.14 To eliminate intermodulation distortion, the colour sub-carrier of the system may be further amplitude-modulated by a signal depending on the luminance signal components which lie within the frequency band of the chrominance signal.

2.9 At the beginning of the line, the frequencies corresponding to the absence of chrominance components are controlled so that they are either in the same phase as, or in phase opposition to, a permanent sinusoidal signal of frequency:

$$f_{RR} = 282.f_H = (282 \times 15\,625)\ \text{Hz} \quad \text{for}\ f_{OR}$$

$$f_{BB} = 272.f_H = (272 \times 15\,625)\ \text{Hz} \quad \text{for}\ f_{OB}$$

A phase change of 180° is carried out during one line at every third line and additionally at every alternate field, producing the cycle 0–0–180° at odd fields and 180°–180°–0 at even fields.

2.10 The chrominance signal is subject to a high-frequency amplitude pre-correction by means of a corrective network with a transmission factor expressed by the formula:

$$A_{HF}(f) = (1 + j.16F)/(1 + j.1{\cdot}26F)$$

$$\text{where } F = f/f_0 - f_0/f \text{ and } f_0 = 4286{\cdot}00\ \text{kHz}$$

The nominal curve of the high-frequency correction is shown in Fig. 5.

2.11 The nominal peak-to-peak amplitude of the colour sub-carrier at the minimum transmission factor of the high-frequency corrective network specified in § 2.10 is 23% of that of the luminance signal.

2.12 The colour synchronizing signals (line identification) required for synchronous operation of the receiving and transmitting switches are transmitted during 9 lines of the field blanking interval, i.e. on lines 7 to 15 in the first field and 320 to 328 in the second field.

These identification lines are made by the colour sub-carrier which is frequency-modulated sequentially by the signals:

— D'_R varying trapezoidally, linear at the beginning of the line for 15 ± 5 μs between 0 and +1·25 followed by a porch at the level +1·25 ±0·13;

— D'_B varying trapezoidally, linear at the beginning of the line for 20 ± 10 μs between 0 and −1·50 followed by a porch at the level −1·50 ±0·15.

The colour synchronizing signals have the appearance shown in Figs. 6 (*a*) and 6 (*b*) before modulation of the sub-carrier and the appearance shown in Fig. 6 (*c*) after its modulation.

2.13 The chrominance signal is suppressed:

— during a time interval of 6·7 to 7·8 μs beginning with the line blanking signal;

— during a time interval beginning with the field blanking signal but excluding the transmission time of the colour synchronizing signals defined in § 2.12.

2.14 To eliminate intermodulation distortion, the colour sub-carrier of the system may be further amplitude-modulated by a signal depending on the luminance signal components which lie within the frequency band of the chrominance signal.

2.15 The luminance signal is transmitted in the nominal frequency band of the black-and-white system from which it is derived.

3. **General transmission characteristics of the video and sound signals** (transmission by radio channel)

The general characteristics of the transmitted signal correspond to the C.C.I.R. standards for the 625-line black-and-white television system from which the signal is derived. (See Report 308-2.)

D. SPECIFICATION OF THE SECAM IV COLOUR TELEVISION SYSTEM *

In view of Doc. XI/162 (Belgium), 1963-1966, with reference to the NIIR—SECAM IV colour television system, the delegations of France and the U.S.S.R. consider it necessary to publish on behalf of their respective Administrations the documents annexed hereto which describe the said SECAM IV system that has been jointly developed and tested by French and Soviet experts.

Both delegations consider that the annexed documents constitute the only source of information capable of giving a precise idea of this version of the SECAM system.

Both delegations wish to point out that the SECAM III version is better prepared for industrial production than the SECAM IV variant, that successful international demonstrations have been made of it in transmissions by radio-relay and via the Soviet satellite Molniya I, whereas the SECAM IV version—although also at a high technical level—has no decisive advantage over SECAM III and is still being developed. France and the U.S.S.R. therefore prefer the SECAM III version.

CHIEF TECHNICAL CHARACTERISTICS

1. **Signals transmitted**

SECAM IV is compatible with standard black-and-white 625-line television systems, except system N. The luminance signal is obtained from gamma-corrected primary signals E'_R, E'_G, E'_B, and corresponds to the equation:

$$E'_Y = 0{\cdot}30\,E'_R + 0{\cdot}59\,E'_G + 0{\cdot}11\,E'_B$$

The colour information is transmitted by two colour-difference signals:

$$D'_R = \frac{1}{1{\cdot}14}(E'_R - E'_Y)$$

$$D'_B = \frac{1}{2{\cdot}03}(E'_B - E'_Y)$$

Before modulation, the frequency band of the colour-difference signals occupies more than 1·5 MHz.

2. **Transmission procedure**

The colour-difference signals are transmitted by modulation of a sub-carrier. They are differentiated from one line to the next as follows:

Signal transmitted during one of the lines

$$Es_1 = \sqrt{D'^2_R + D'^2_B} + E_p \cos[\omega_0 t + \varphi(t)]$$

* This specification is reproduced from Doc. XI/169 (France and U.S.S.R.), 1963-1966.

Signal transmitted during the following line

$$E_{S_1} = \sqrt{D_R'^2 + D_B'^2} + E_p \cos(\omega_0 t + \varphi_0)$$

where E_p is a d.c. voltage equal to 10% of the maximum signal

$$\sqrt{D_R'^2 + D_B'^2}$$

and where

$$\varphi(t) = \text{arc tan}\,(D_B'/D_R')$$

3. **Frequency of the colour sub-carrier**

The frequency of the colour sub-carrier is equal to: $f_0 = 4{\cdot}43361875$ MHz. It is related to the line sweep frequency $f_{line} = 15\,625$ Hz by the following equation:

$$f_0 = (284 - 1/4)\, f_{line} + 25 \text{ Hz}.$$

4. **Colour synchronization signal**

The receiver switch is synchronized by synchronization signals transmitted with the composite video signal. They represent six wave trains of the colour sub-carrier, each train lasting about 40 μs. They are transmitted during the field returns in the 6th–11th lines of the first field and in the 319th–324th lines of the second field. During the even lines, the sub-carrier phase in the train is $\varphi = 90°$, and during all the odd lines $\varphi = 180°$. The amplitude of each wave train is equal to 30% of the composite signal E_Y' measured between the white and black levels.

5. **Reception procedure**

The colour-difference signals D_R' and D_B' are obtained by multiplication of the transmitted signals $E_{(2n+1)}$ and E_{2n}, each signal being delayed in turn by the duration of one line. The level of the signal E_{2n} must be 10 to 20 times higher than that of the signal $E_{(2n+1)}$.

To obtain the correct polarity for the signals E_{B-Y}' and E_{R-Y}' at each line, a switch working to the line periodicity is used.

ANNEX

REPORT BY SUB-GROUP XI-A-2 TO THE XIth PLENARY ASSEMBLY, OSLO, 1966

Sub-Group XI-A-2 met on 7 and 8 July, under the chairmanship of Mr. E. Esping and with the participation of the following delegations: United States of America, France, Italy, Netherlands, Federal Republic of Germany, United Kingdom, Switzerland, Czechoslovak Socialist Republic, U.S.S.R. and Federal Socialist Republic of Yugoslavia.

1. The Sub-Group considered first whether a compromise could be reached on recommending a single world-wide colour television system. The conclusion was quickly reached that this was impossible in view of the fact that the system already in public service in countries using the 525-line standard was not generally acceptable elsewhere. The U.S.A. suggested that for international programme exchange, colour television signals could be relayed on 625 lines either in NTSC or PAL form, according to the wishes of the receiving country. Alternatively,

the delegation of the United States of America suggested that world-wide adoption of the ART (Additional Reference carrier Transmission) system for broadcasting would in its view offer the advantage of permitting the use of existing NTSC receivers on the ART transmission. In the view of the delegation of the U.S.A. this system would also appear to offer the same advantages as SECAM or PAL. These two proposals received no support.

2. Attention was therefore turned to the possibility of agreeing on a single system of 625-line colour television for use in countries which have adopted this line standard, and to begin with in the area in which several countries have announced their intention of starting regular colour television services towards the end of 1967.

3. During the discussions, Doc. XI/179 (Denmark) was referred to by the U.K. delegate. A compromise system is proposed in this document. The delegate specially referred to § 8 in the document: "The Danish delegation suggests that a questionnaire be addressed to those members of the Study Group operating or contemplating the introduction of 625-line colour television, asking whether they would be prepared to support this system if all other delegations were prepared to do the same."

To find out if unanimous agreement on this suggestion would be possible, the Chairman consulted the members of the Sub-Group. The result of this consultation was that no agreement could be reached.

4. Noting that the SECAM IV system has been the only system proposed, even by certain supporters of PAL, as being capable of constituting a possible compromise leading to the adoption of a single European colour television standard, the French delegation—speaking on behalf of the other delegations present who have already accepted SECAM III—declared itself ready to abandon SECAM III and to adopt SECAM IV.

Such a decision would necessarily imply a delay (which could be reckoned at about six months) in the introduction of a regular colour television system in countries of the European area which have decided to introduce such a system in autumn 1967. All the countries interested in the introduction of a colour television system in Europe should put this period to good use by pooling the necessary resources to perfect the final version of SECAM IV.

Since the possible adoption of SECAM IV by France and its partners represents the extreme limit of what these countries are prepared to sacrifice in this respect, it goes without saying that all the countries interested in starting a regular colour television system in autumn 1967 will have to participate, within the full measure of their resources, in this research and development work during the period of six months or more in which the final version of SECAM IV is perfected. It is also understood that they will accordingly refrain from any measures which, particularly as regards the manufacture of receivers, might run counter —directly or indirectly—to the common work which they would have defined.

Moreover, in view of the imperative need to avoid any useless delay, it should be clearly understood that agreement to the above-mentioned principles should be given as soon as possible, and in any case early enough before the end of the present Plenary Assembly of the C.C.I.R.

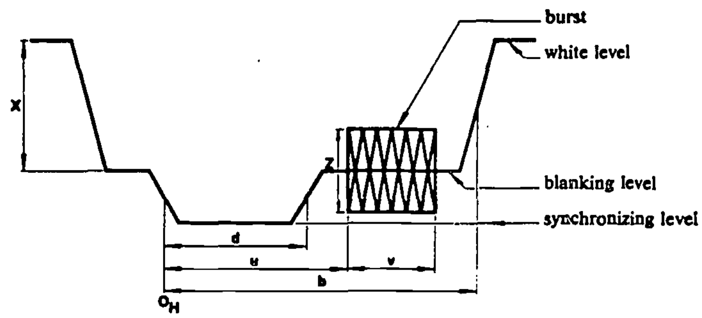
Having heard the replies of the delegations of the United Kingdom and of the Federal Republic of Germany (given below), the French delegation, noting that these two delegations did not accept its proposal which was supported by the delegations of the Czechoslovak Socialist Republic, the U.S.S.R. and the Federal Socialist Republic of Yugoslavia, declared that it was obliged to withdraw it.

Statement of the delegations of the Federal Republic of Germany and of the United Kingdom

The delegations of the Federal Republic of Germany and of the United Kingdom said that, quite apart from the fact that the system SECAM IV, unlike PAL, is not yet ready for commercial exploitation, the proposal advanced by the French delegation raised other difficulties. The questions (*a*) of setting back the dates by which colour television services would be introduced, involving modification of the decisions of governments and (*b*) of agreeing to abstain from all industrial development incompatible with the joint development of SECAM IV (see the text of the French proposal), were quite outside the competence of the C.C.I.R.

It would therefore be clearly impossible to obtain decisions on these matters by the time limit set by the French proposal. Nevertheless, it was desired to have a more precise definition of the proposals for the consideration of Administrations and governments.

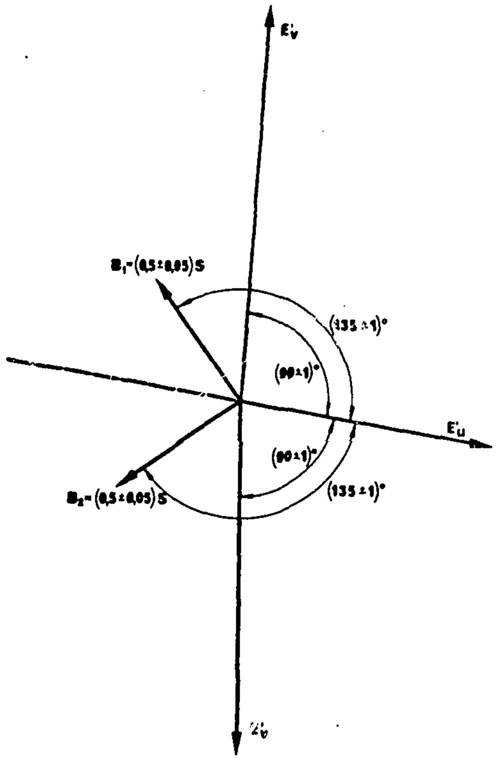
In any case, the delegations of the Federal Republic of Germany and the United Kingdom would be happy to continue the joint study of SECAM IV.



Item	Systems	
	I, B, G and *H*	*M*
Z	$\frac{3}{7} X \pm \frac{0 \cdot 3}{7} X$	
b	10·5 μs	8·9 — 10·2 μs
d	4·7 μs	4·19 — 5·7 μs
u	5·6 μs ± 0·1 μs	5·8 μs ± 0·1 μs
v	2·25 μs ± 0·23 μs	2·52 μs ± 0·28 μs

FIGURE 1

Colour synchronization and chrominance axes



Notes

1. S, the nominal video-sync. pulse magnitude prior to transmission, is taken as equal to 3/7 of the difference between white and blanking levels.
2. On odd lines of the first and second fields and on even lines of the third and fourth fields the burst is B_1. On even lines of the first and second fields and on odd lines of the third and fourth fields the burst is B_2.
3. $0{\cdot}95 < B_1/B_2 < 1{\cdot}05$ as transmitted.
4. The burst shall be omitted during 9 lines in the field blanking interval in the manner shown in Fig. 2.

FIGURE 1 (contd.)

Colour synchronization and chrominance axes

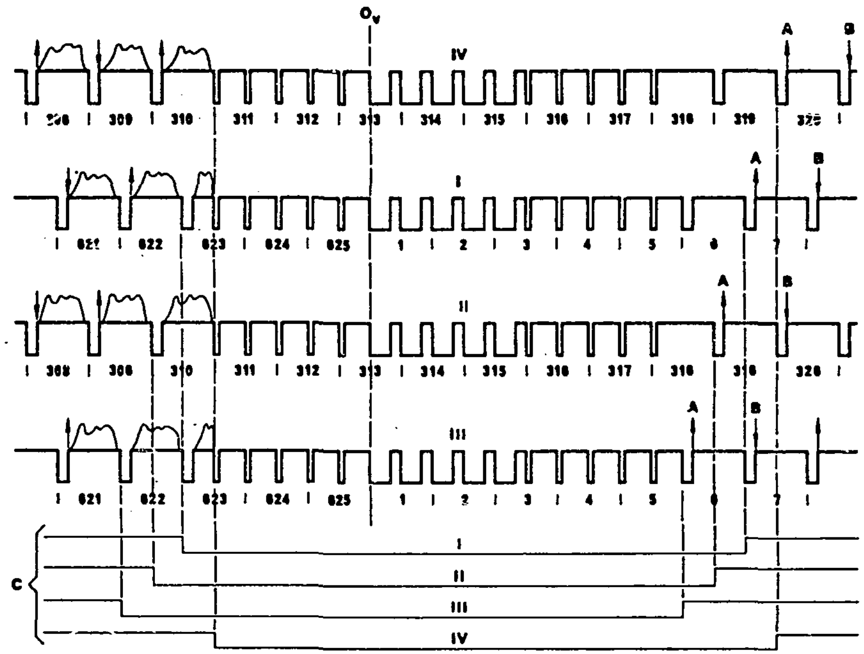


FIGURE 2a

PAL: Field blanking interval—Systems I, B, G and H

O_v: field synchronizing datum.
I, II, III, IV: first, second, third and fourth fields.
A: phase of burst; nominal value +135°.
B: phase of burst; nominal value −135°.
C: burst blanking intervals.

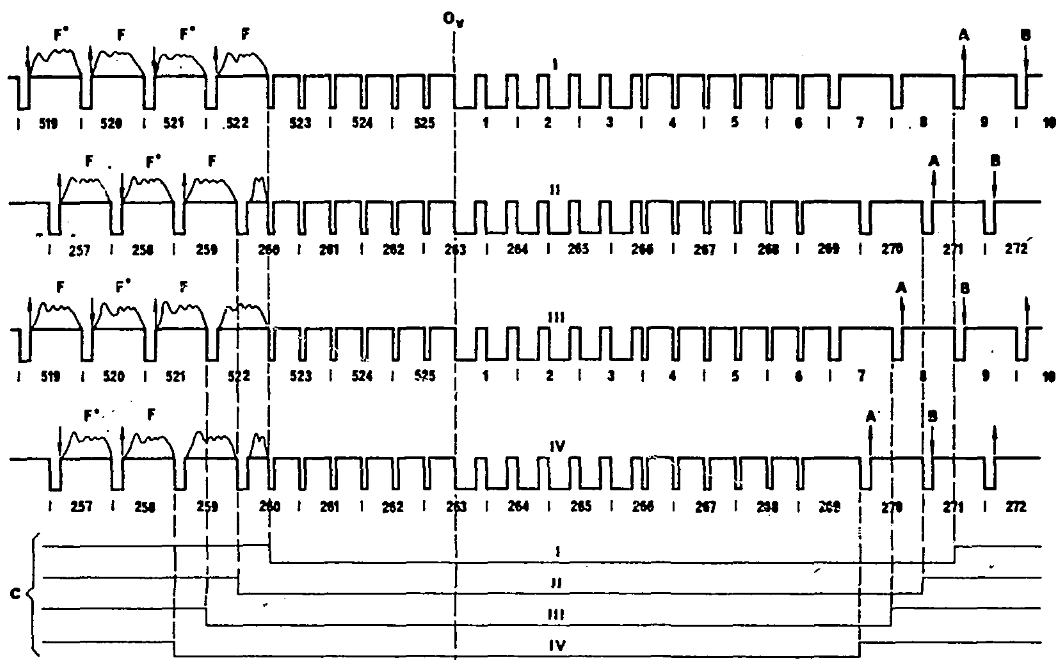
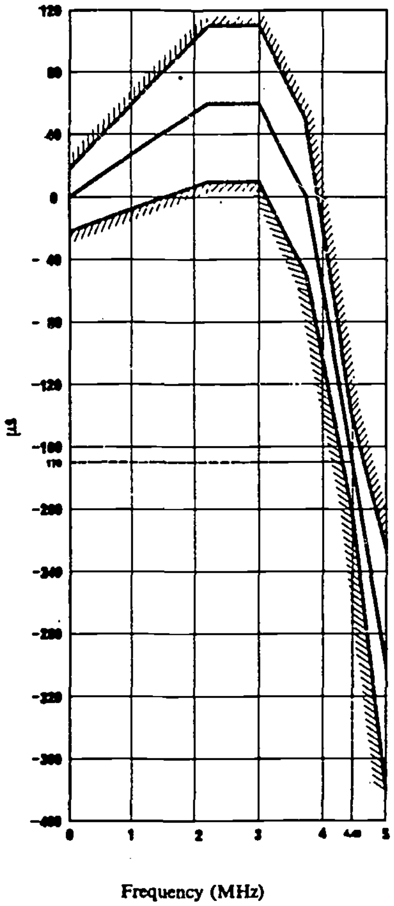


FIGURE 2b

PAL: field blanking interval—System M

O_v:	field synchronizing datum.
I, II, III, IV:	first, second, third and fourth fields.
A:	phase of burst; nominal value +135°.
B:	phase of burst; nominal value −135°.
C:	burst blanking intervals.



Table

2·25 MHz	60 ns ± 50 µs
3·00 MHz	60 ns ± 50 µs
3·75 MHz	0 ns ± 50 µs
4·43 MHz	− 170 ns ± 35 µs
5·00 MHz	− 300 ns ± 75 µs

FIGURE 3 8

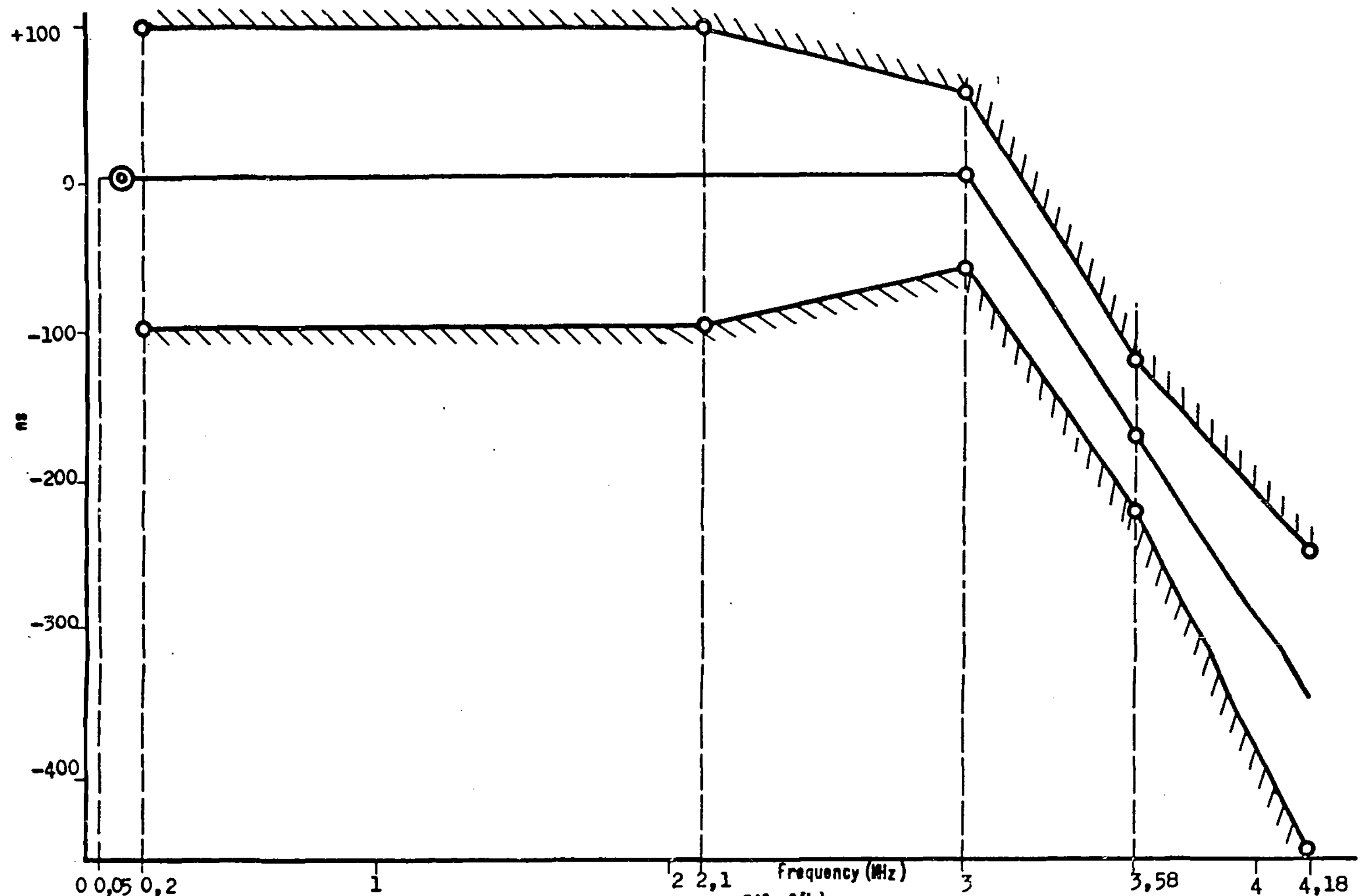


FIG. 3(b)

M-PAL system

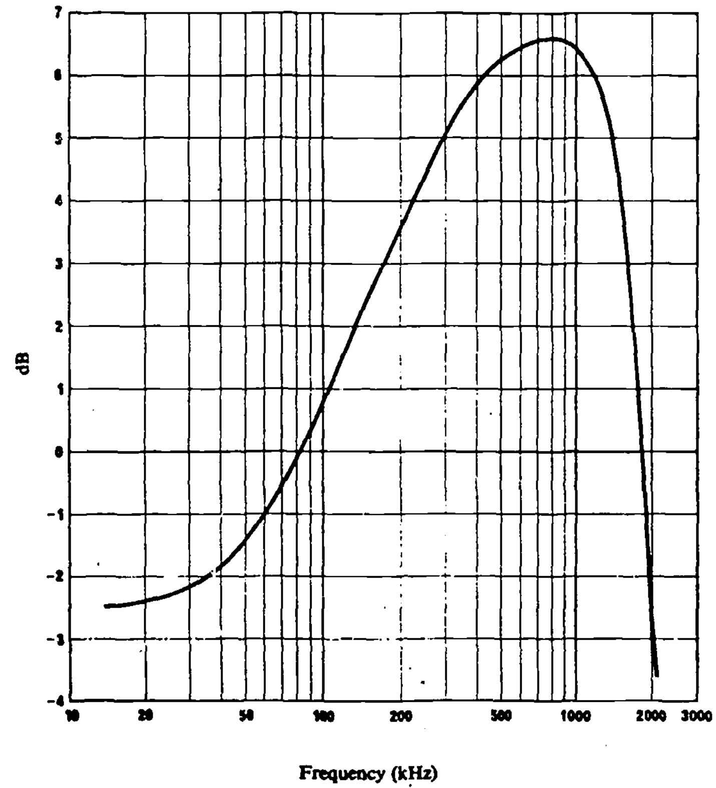


FIGURE 4

Curve showing the low-frequency correction and limitation of the spectrum of the signals D'_R and D'_B

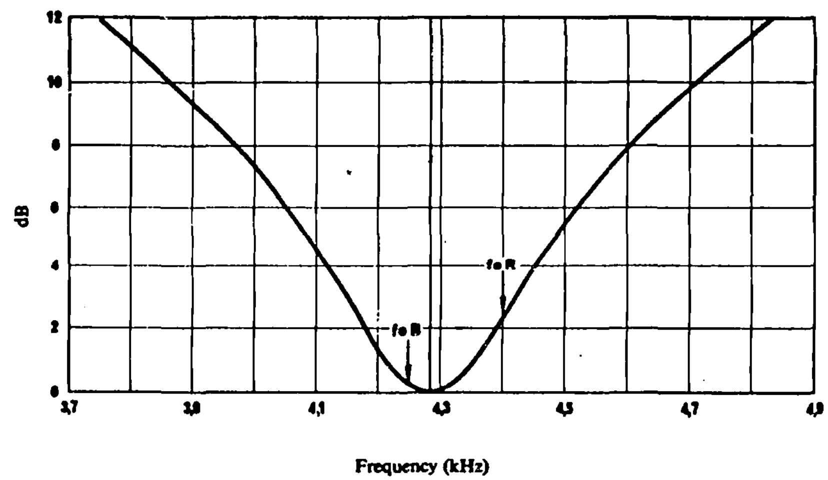
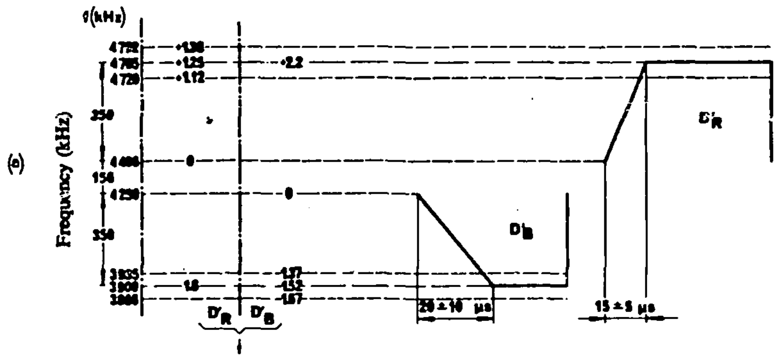


FIGURE 5

Nominal curve of frequency correction



Relative values of the modulating signal

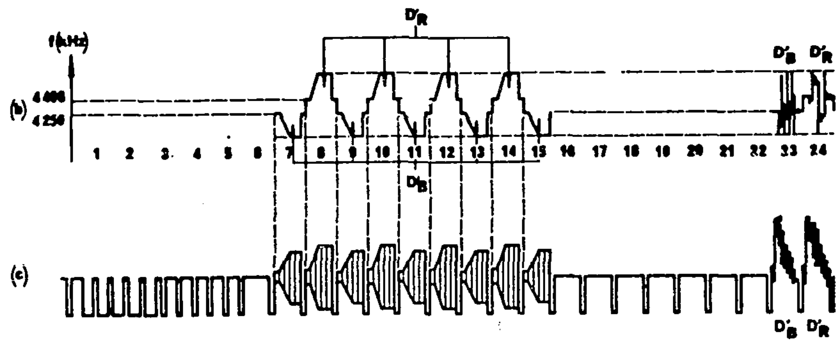


FIGURE 6

Colour synchronizing signals

II-5 NCTA Technical Standards

1. CATV amplifier distortion characteristics (NCTA-002-0267)
2. Graphic symbols for electrical and electronic devices to be designated on CATV systems layout drawings (NCTA-003-0668)
3. Noise level in cable systems (NCTA-005-0669)

ELECTRICAL PERFORMANCE STANDARDS FOR TELEVISION BROADCAST TRANSMITTERS

Channels 2- 6 (54 mc- 88 mc)
7-13 (174 mc-216 mc)
14-83 (470 mc-890 mc)

(From TR-104-B and Standards Proposal No. 656 formulated under the cognizance of EIA Engineering Subcommittee TR4.1 on Program Transmitters and Committee TR-4 on Television Broadcast Transmitting Equipment.)

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report is concerned with the system control facilities in broadband communication systems. In CATV systems these are the head-ends and central processors. Technical problems and needs are summarized in Section 1 immediately following. Section 2 offers a cursory overview of systems and mention of processors is made only incidentally. In Section 3 the question of the computer needs laid upon the central processor at head-ends or subhead-ends by particular service requirements is looked at, and in Section 4 the problems of coupling the computer into a communications system are considered. Privacy and security, a worrisome area in time-shared computers to say nothing of CATV systems, is considered in Section 5 while performance standards, present and future, are treated in Section 6. In Section 7 we look at measurements required by current FCC regulations, those which the cable operator will want to make

(continued on next page)

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